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THE

MODERN PSYCHOLOGY

BY

PROFESSOR R. J. A. BERRY
M.D., F.R.C.S., F.R.S. Edin.

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UNIVERSITY OF MELBOURNE

THE STEWART LECTURES

14TH, 18TH AND 21ST NOVEMBER, 1921

BY

PROFESSOR R. J. A. BERRY, M.D., F.R.C.S., F.R.S. Edin.

ON

THE MODERN PSYCHOLOGY

WITH EIGHT ILLUSTRATIONS

INTRODUCTION

To the Stewart Bequest the University owes its Stewart Lectures in Medicine and in Surgery, its Stewart Scholars in Anatomy, in Medicine, and in Surgery, provision for apparatus in these and other Departments, and the institution of the biennial course of Stewart Lectures on some subject of national importance to Australia.

Indirectly the same benefaction enabled the University to appoint its Stewart Lecturers in Anatomy and in Pathology, and assisted the appointment of a Lecturer in Physiology. Provision has also been made towards a future Department of Neurology.

The bequest of over £25,000 was under the will of Dr. James Stewart, F.R.C.S.I., who came, as a young man, from the North of Ireland, and practised in Ballarat from 1853 to 1875-76. He was the second Mayor of Ballarat West, and one of the original Honorary Medical Officers of the Ballarat Hospital. Having made a large fortune in successful practice, and by mining investment, he retired to England and died at Rickmanshurst, Herts, on June 30th, 1906, aged 76.

In addition to his bequest to the University, Dr. Stewart left large sums to educational and charitable institutions in Ballarat, and to Trinity, Ormond, and Queen's Colleges for Theological purposes.

The first course of Stewart Lectures was given in 1911, by Professor Osborne, on "Climatology"; the second in 1913, by Dr. Breinl, on "Tropical Medicine and Conditions Affecting White Settlement in Tropical Australia." War then intervened, and now the third course is by Professor Berry, on "The Modern Psychology."

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NOTE.—The first five figures are from "The Central Nervous System," Vol. 3, Part 2, of the second revised and illustrated edition of the author's "Practical Anatomy, 1922," and are here included by kind permission of the publishers, Messrs. Robertson and Mullens Ltd., Melbourne. The remaining figures have been specially prepared for these lectures.

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UNIVERSITY OF MELBOURNE.

The Stewart Lectures, delivered on the 14th, 18th, and 21st November, 1921, by Professor R. J. A. Berry, M.D., F.R.C.S., F.R.S., Edin., on

THE MODERN PSYCHOLOGY.

LECTURE 1.—THE EVOLUTION OF A BRAIN AS THE PHYSICAL ORGAN OF MIND.

The Chancellor of the University, Sir John Macfarland, presiding.

Mr. Chancellor, Mr. Dean, Ladies and Gentlemen—

Every human being is developed from a single cell or ovum, which, after fertilisation, undergoes a long and complex series of changes, by means of which there is produced a new individual which, within the limits of ordinary variation, is like the parents that gave it birth. From the study of these changes are derived our conceptions of the nature of sex, of heredity, of variation, of differentiation, and of many of our most important notions concerning evolution, both of the individual and of the race.

Subsequent to birth a further series of changes occurs, to which the term *development* is applied. These changes include the processes of growth, the development of muscle, the adaptation of the brain to its intellectual functions, and many others. Any or all of these post-natal changes may not proceed to full development, in which case the child will be more or less seriously hindered from performing the normal functions of adult life. If it be the nerve cells which do not attain full development, some form of feeble-mindedness must result.

Subsequent to fertilisation the single-celled ovum divides into two segments or blastomeres. These divide to form a group of four segments, which again cleave into eight, and this process of binary cell division is continued until the original single-celled ovum becomes converted into a many celled mass, termed a *morula.* From this multi-celled morula there will eventually be developed the countless millions of cells which go to form the human body. With further development these cells will become specially modified to form the bone cells, liver cells, muscle cells, brain cells, and so on.

The human brain is entirely made up of many millions of highly specialised brain cells, termed *neurones,* embedded

in a supporting framework of non-nervous cells, or *neuroglia.* The neurone is thus the unit of brain structure. It is a microscopic object, which cannot be seen with the naked eye, but when a sufficient number of neurones, running into thousands of millions, are massed together, there is produced a solid and tangible object, the human brain—the organ of intelligence.

Psychology may be defined (Macdougall) as "the positive science of the behaviour of living things . . . when we say that they exhibit behaviour, we mean that they seem to have an intrinsic power of self-determination and to pursue actively, or with effort, their own welfare and their own ends."

Neurology teaches that every living thing reacts to stimuli derived from two great sources—the internal bodily or somatic world, and the external physical world. The mode of re-action to these stimuli constitutes behaviour, and these re-actions, and consequently behaviour itself, depend entirely on the number, nature and relative state of development of the neurones. As function depends on structure, psychology and neurology are mutually inter-dependent, and should be fused into a single science—Neuro-psychology, or the modern psychology.

In view of the large amount of attention which is now being devoted, often by those who are quite ignorant of brain structure, to the phenomena of psychology, psycho-analysis, self-introspection, and the borderlands of spiritualism, it cannot be too strongly urged, and remembered, that the formula is—*no neurone, no mind.* Just as with electric action, an insufficient number of batteries, an imperfectly connected series of batteries, or an improper insulation of the electric wires, give indifferent results, so also is it with the human brain. An insufficient number of neurones, an imperfectly connected series of neurones, or an imperfect insulation (myelination) of their axons give marked differences in the display of intelligent action, that is, in the behaviour of the individual. Depending on the degree of arrested neuronic development, there results some form of idiocy, imbecility, moronity, or feeble-mindedness, in all of which cases the neurological re-action of the individual to his environment, that is, his behaviour, is strikingly different from that of the normal individual. That this is due to lack of neurones is abundantly proved by a study of the brain weights of microcephalic idiots, and more recently, of the relative thicknesses of the cortical layers of the brain. All neurologists are agreed that "with brains of a smaller size than 930 grammes we can scarcely expect a human intelligence."

It has already been seen that every human being is developed

from a single cell or ovum, which, after fertilisation, goes on dividing and redividing until many countless millions of cells are produced, which become developed and specialised for their own particular functions. Those of the cells which are to become brain cells become differentiated at a very early period of embryonic life, and it is soon possible to classify them into two groups—spongioblasts or non-nervous cells, which form the supporting neuroglial framework, and neuroblasts, or true nerve cells, which come to lie within the meshes of the spongioblasts. Excessive development of the spongioblasts will result in the large heavy brain of ordinary or deficient intelligence, whereas excessive development of the neuroblasts will result in the large multi-neuronic brain of high intelligence or genius.

Intelligence depends on two factors—the number and nature of the neurones, and the number and nature of the incoming afferent impressions. The neurones comprise (1), the exteroceptive or distance receptor neurones, which convey to the brain sensations aroused by forms of energy in the outer physical world. Such neurones translate light, sound, chemical activity, &c., into nerve impulses, and transmit them to the central nervous system. (2). The enteroceptive afferent neurones transmit impressions derived from the internal bodily organs. Amongst these are impressions concerned with internal, or visceral, organs, or vague general sensations, such as hunger, thirst, the sexual appetite, &c. (3), The proprioceptive afferent neurones which receive stimulation from the state of the tissues themselves, and inform us as to the activity of the muscles, joints, the position of the body in space, &c. The great importance of these incoming afferent impressions is also proved by the facts that the neurones concerned (afferent or receptor) are more numerous than the outgoing neurones (efferent or effector), and are also the first to be developed and to assume their medullary sheaths. The acquisition of the medullary sheath is the sign that the neurone is capable of functioning, and afferent neurones always myelinate before efferent ones. It follows, therefore, that before there can be any display of "mind" or "intelligent" action, there must be an inpouring of afferent impressions. The brain must receive before it can give out the phenomena associated with "mind." Afferent neurones are continually receiving stimuli from the external physical world and the internal bodily world, are continually transforming such stimuli into nerve impulses, and are as continually transmitting them to the brain. Such impulses obviously cannot be lost within the brain, but must effect some result. The individual thus re-acts to his surroundings (neurology), or

FIGURE 1.

A diagram showing (a) the various types of neuronic reflex arcs in the central nervous system, and (b) that psychological manifestations of "mind" are to be sought in combinations of neuronic arcs of a complex pattern. (Berry.)

Afferent or receptor neurones are shown with a solid black circular cell body.

Efferent or effector neurones with a solid black trianguiar cell body.

Dispersal (inter-nuncial) neurones with a clear circular cell body.

Efferent Purkinje cells of the cerebellum with a dotted circular cell body.

1. Shows the simplest of all neuronic reflex arcs. Here a bipolar afferent or receptor neurone passes over to 1a, an efferent or effector neurone. If this type occurs in man at all, it is probably represented by the knee-jerk reflex neuronic arc.

2. Shows the more usual type of neuronic reflex arc, where there is interposed, between the receptor, 2, and the effector, 2b, a commissural or association neurone, 2a. This is the type through which many of the simpler spinal cord reflexes of man are effected.

3. Shows a receptor neurone entering the spinal cord, and dividing therein, into ascending and descending branches. It is thus brought into relationship with two or more segments of the spinal cord, and eventually with several effector neurones, 3e and 3f, through commissural or association neurones, 3c and 3d, in the usual way. To this type belong many of the vital reflexes of the medulla.

4. Shows a receptor neurone establishing contact with lower spinal cord levels, 4b, and with higher levels of the brain stem, and the cerebral cortex through a series of neurones, 4a, the fibres of the fillet, and the thalamo-cortical fibres. Impulses which traverse this route may be dispersed through the thalamus, by a series of inter-nuncial neurones, to the corpus striatum, and thence through the striate effector neurones, thus following the path of the primitive thalamo-striate brain of some of the lower animals. More usually, however, they are continued into the cerebral cortex, and are dispersed all over that cortex by specially modified types of inter-nuncial neurones (Golgi second type, Martinotti, Cajal, etc., represented by clear white circles). Those impulses which traverse the infra-granular cortex are associated with the animal, sexual, and other instinctive reflexes, whilst those which traverse the supra-granular cortex are largely of an educational and psychic character. It is thus clear that the neuronic machinery of "mind" differs in no way from that of the simple neuronic reflex, except in its much greater complexity, and in the fact that the "inter-nuncial" neurones are apparently of a later evolutionary variety, and of a specially constructed type.

It should be particularly noted that the short inter-nuncial neurone is chiefly located in the cerebral and cerebellar cortices, and is hardly present at all in the spinal cord. It is, therefore, clearly a necssary and integral part of the controlling mechanism of a brain, and of the psychical phenomena of mind.

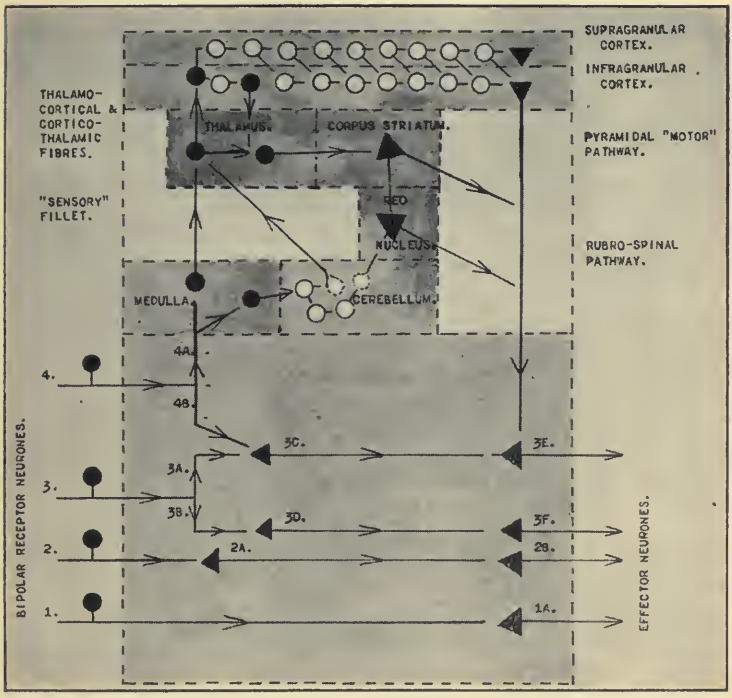


FIGURE 1.

A diagram showing (a) the various types of neuronic reflex arcs in the central nervous system, and (b) that psychological manifestations of "mind" are to be sought in combinations of neuronic arcs of a complex pattern. (Berry.)

behaves (psychology). The nerve mechanism by which this is accomplished is always the same, namely, through combinations of reflex arcs. Man is, therefore, entirely a reflex animal, and only differs from a simple reflex organism, like the earthworm, in the extraordinary complexity of his neuronic reflex arcs which attain their highest development in the brain.

As regards its structural units, the central nervous system of every animal, man included, is built up of reflex neuronic arcs, and, functionally, of reflex actions.

A *neurone* is a highly specialised nerve cell, which possesses a cell body, one or more processes termed dendrons, conducting nervous impulses towards the cell body, and usually one long or short process, the axon, conducting away from the cell body. This last process is usually insulated by a medullary sheath, and until that sheath is formed the neurone cannot function. The most distinctive functional properties of the nervous system are those of irritability, conduction, and correlation, but these functions are effected, not so much by individual neurones, as by various types of connections between different neurones in the nerve centres. As regards the neurones themselves, their most striking property is that of conduction, and they are always arranged in combinations which form neuronic arcs. (See Figure 1.)

In its simplest form a *neuronic arc* comprises (1), a receptor or afferent neurone, conveying impulses centrally; (2), usually, but perhaps not always, a short interposed or internuncial neurone: these are conspicuous by their relative absence in the spinal cord, but are present in millions in the cortices of the cerebellum and cerebrum, and are a special histological feature thereof. Their function is probably to act as a reinforcing neurone, or as a dispersal station, through which the impulses are dispersed over a large series of other neuronic arcs, or, possibly, they may act as storage stations for nerve impulses. In the last case they would form a physical basis for memory. (3), An effector or efferent neurone, by means of which is effected some action in response to the afferent impulses received.

The form of the nervous system is always correlated with the behaviour of the animal possessing it. In other words, its psychology or behaviour is entirely dependent on its neurology. In the segmented worms, such as the common earthworm, the central nervous system consists of a chain of ganglia, connected by a longitudinal cord along the ventral side. Each of these ganglia is connected by means of receptor and effector neurones, with the skin and muscle of its own segment. Each segment of the earthworm has, therefore, a certain measure of physiological independence, and can act

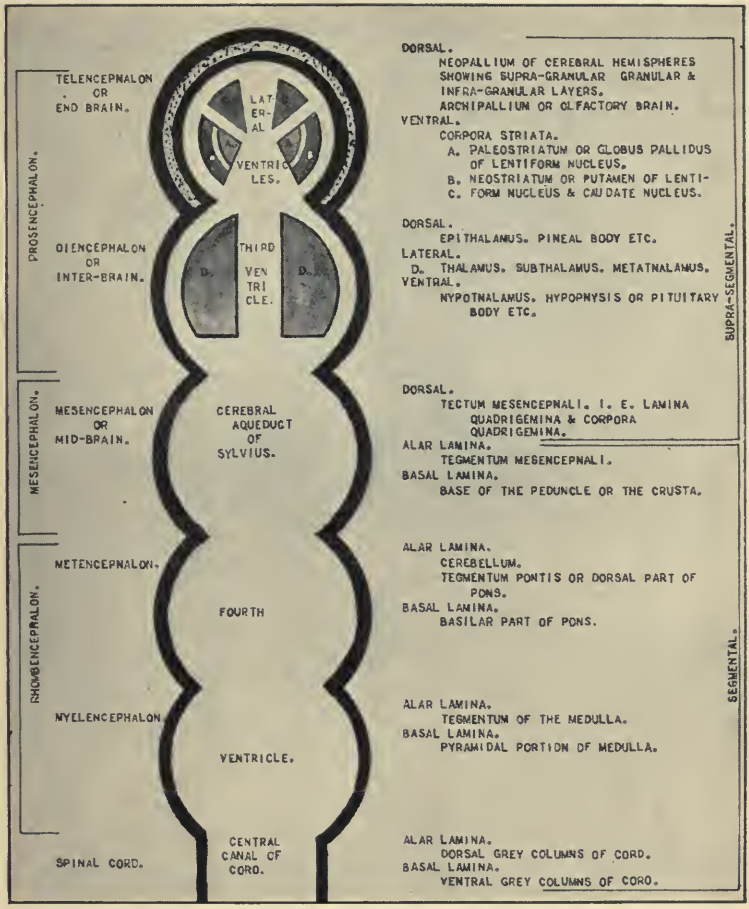


FIGURE 2.

A diagram to show the primary and secondary cerebral vesicles, the parts of the adult central nervous system developed therefrom, the fate of the primitive cavity of the neural tube, as well as the homologies of the alar and basal laminae, and the subdivision of the central nervous system of man into a segmental and a supra-segmental part. (Berry.)

as a unit, and every segment is composed of a neuronic arc —the ganglion representing the internuncial neurone between the receptor and effector limbs of that arc. Nervous co-ordination is obtained by the linking together of the various segmental ganglia by means of the longitudinal chain mentioned, and by the presence at the head end of a supra-oesophageal ganglion, sometimes termed the brain.

"Most of the types of nervous systems found in the animal kingdom are represented in two distinct and divergent lines of evolution, one adapted especially well for the reflex and instinctive mode of life and found in the worms, insects, and their allies, and the other found in the vertebrates and culminating in the human brain, with its remarkable capacity for individually acquired and conscious functions." (Herrick.)

Between the simple neuronic reflex arcs of the nervous system of the earthworm, with their simple re-actions to physical stimuli, and the complex brain of man with its psychic manifestations, there is a vast gulf of time and the creation of an immense number of animal forms, but the mechanism is always the neuronic reflex arc.

A more complicated form of neuronic reflex arc is that known as the *sensori-motor reflex*. Here the neuronic mechanism is more complicated, as the central process of the afferent or receptor neurone may divide into two, one part going to the effector neurone in the spinal cord, and the other passing up to the brain. If the nerve impulse pass over the former the resultant action will be unconscious, if over the latter conscious sensation will be aroused. As examples of reflexes of this nature in man, may be mentioned coughing in bronchitis, flushing of the skin on going into cold air, and the effect of martial music on the heart.

Through the medulla and pons occur many other reflex actions, such as those concerned with the vital phenomena of breathing, the heart beat, and many others.

At the head end of successive evolutionary types of animals Nature continually adds on a new *co-ordinating brain*. There is first the mid-brain, then the thalamo-striate brain, next the infra-granular cerebral cortex of mammals, and lastly, there has been added, in man, a supra-granular cortex with association areas. In every instance the nerve mechanism is the neuronic reflex arc, which becomes more and more complex with each evolutionary addition. If we had a perfect knowledge of all the connections of these excessively complex neuronic arcs in the more recent evolutionary additions to the central nervous system, and knew the nerve paths affected by any given stimulus, "we should be able to prophesy exactly

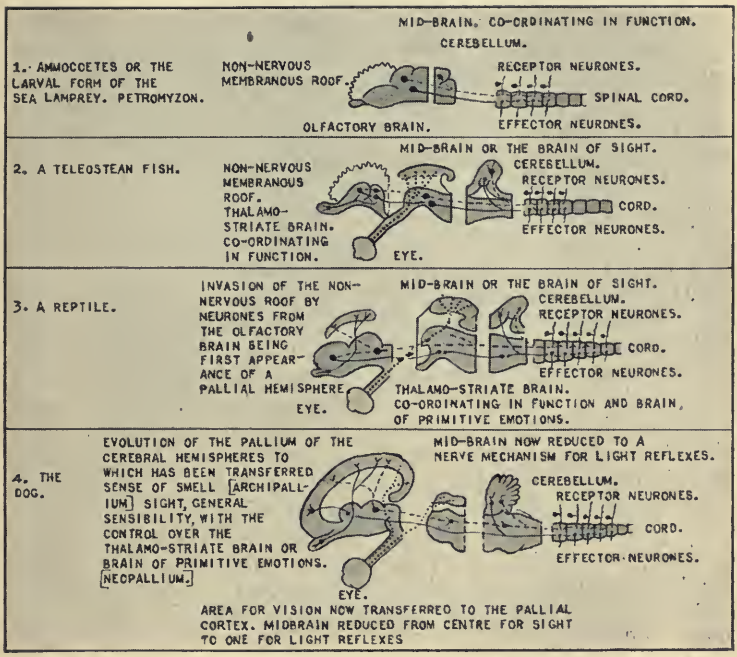

MID-BRAIN, CO-ORDINATING IN FUNCTION.
CEREBELLUM.
1. AMMOCOETES OR THE LARVAL FORM OF THE SEA LAMPREY. PETROMYZON.
NON-NERVOUS MEMBRANOUS ROOF.
RECEPTOR NEURONES.
SPINAL CORD.
OLFACTORY BRAIN.
EFFECTOR NEURONES.
MID-BRAIN OR THE BRAIN OF SIGHT.
2. A TELEOSTEAN FISH.
NON-NERVOUS MEMBRANOUS ROOF.
THALAMO-STRIATE BRAIN. CO-ORDINATING IN FUNCTION.
CEREBELLUM.
RECEPTOR NEURONES.
CORD.
EFFECTOR NEURONES.
EYE.
3. A REPTILE.
INVASION OF THE NON-NERVOUS ROOF BY NEURONES FROM THE OLFACTORY BRAIN BEING FIRST APPEARANCE OF A PALLIAL HEMISPHERE.
MID-BRAIN OR THE BRAIN OF SIGHT.
CEREBELLUM.
RECEPTOR NEURONES.
CORD.
EFFECTOR NEURONES.
EYE.
THALAMO-STRIATE BRAIN. CO-ORDINATING IN FUNCTION AND BRAIN, OF PRIMITIVE EMOTIONS.
4. THE DOG.
EVOLUTION OF THE PALLIUM OF THE CEREBRAL HEMISPHERES TO WHICH HAS BEEN TRANSFERRED SENSE OF SMELL [ARCHIPALLIUM] SIGHT, GENERAL SENSIBILITY, WITH THE CONTROL OVER THE THALAMO-STRIATE BRAIN OR BRAIN OF PRIMITIVE EMOTIONS. [NEOPALLIUM.]
MID-BRAIN NOW REDUCED TO A NERVE MECHANISM FOR LIGHT REFLEXES.
CEREBELLUM.
RECEPTOR NEURONES.
CORD.
EFFECTOR NEURONES.
EYE.
AREA FOR VISION NOW TRANSFERRED TO THE PALLIAL CORTEX. MIDBRAIN REDUCED FROM CENTRE FOR SIGHT TO ONE FOR LIGHT REFLEXES

FIGURE 3.

A diagram, simplified from von Monakow, to illustrate the process of telencephalisation or shifting forward of cerebral function. (Berry.)

Afferent pathways are represented thus: - - - - - - - -
Efferent pathways: ————————
Visual pathways: .....
Olfactory pathways: ————————

the result of such stimulus," that is, what the exact behaviour of the individual would be. "In the cases of the simpler re-actions," both in animal and man, "this is already possible" (Starling), but in the higher parts of the nervous system the enormous complexity of the neuronic arcs and their connections excludes any possibility of our forming more than a general idea as to how the individual will re-act, mentally, to afferent or incoming impressions. The emotional and psychic reflexes, which involve the higher parts of the most recently added parts of the nervous system, are usually regarded as being the special province of Psychology. This, however, is not altogether justifiable, because there is no doubt whatsoever that all psychological phenomena are strictly referable to normal neuronic connections, or to functional or structural alterations therein. Idiots and imbeciles, in whom the neuronic mechanism is grossly lacking, will behave, psychologically, quite differently from more normal individuals. The real difficulty in correlating psychology and neurology lies in the fact that as we pass from the simple reflex neuronic arcs to the highly complex, which involve mind and intelligence, we become less and less familiar with the extraordinary complexity of the paths followed by the neuronic arcs involved. There is, however, no doubt at all that the same type of neuronic machinery which serves for the simpler reflexes is also utilised by nature, though in an immensely more involved form, for the display of the emotions and of mind. Hence the formula, which cannot be too strongly emphasised, "no neurone, no mind."

The dependence of mind on neurones is also proved by embryology and evolution, as well as by histology and pathology. There is no more interesting story than that of the *evolution of a brain as the physical organ of mind.* Every human individual reproduces, in his own development, this evolutionary history. The five secondary cerebral vesicles (see Figure 2), myelencephalon, metencephalon, mesencephalon or mid-brain, diencephalon or inter-brain, and telencephalon or end brain, represent the successive evolutionary additions at the head end, and as each one is added there is a shifting forwards of cerebral function to it, a process which is generally known as *telencephalisation.* (See Figure 3.) This process is very beautifully illustrated by selecting such diverse animal types as the larval form of the sea lamprey, a teleostean fish, a reptile, and a mammal, such as the dog, where there is seen to be a progressive addition to the brain, and a shifting forwards of function in accordance with the requirements of the animal.

In the *sea lamprey* there is a mid-brain only, which is the

general co-ordinating brain for all afferent impressions, including those from the smell-brain. Apart from this, there is no other brain whatsoever, and the cerebral nerve apparatus is roofed in by a non-nervous covering. In the *teleostean fish* the diencephalon makes its appearance, as well as a primitive corpus striatum. This thalamo-striate brain has the co-ordinating functions of the mid-brain shifted to it, and the mid-brain becomes transformed into the brain of sight. To the thalamo-striate brain pass all afferent impulses, including those from the smell brain, and it is roofed in, as before, by a non-nervous membranous roof. With the advent of the *reptile*, life is shifted from water to the land, and the function of smell becomes profoundly modified. Not only is the medium through which impressions of smell are transmitted, altered from water to air, but its functions become modified also, and serve the animal for sexual purposes, in addition to those concerned with food. The sense of smell becomes, therefore, much more important to the animal, and is reflected in its central nervous system. In the reptile, the thalamo-striate brain is no longer sufficient for the co-ordination of all entering afferent impulses, and it is found that the olfactory neurones begin to invade the non-nervous membranous roof, thus producing the beginnings of a pallial cerebral hemisphere. In the *dog*, that is, the mammal, the end brain has become enormously enlarged, and is built up on an infra-granular basis. The neopallium of the mammalian cerebral hemisphere becomes the co-ordinating brain, and to it are shifted the functions of the diencephalon and mid-brain, the latter consequently becomes reduced to a centre for light reflexes, whilst the centre for sight moves forwards to the new pallium of the cerebral hemisphere—hence the explanation of the Argyll-Robertson pupil. After its evolution this pallial hemisphere assumes control over all other parts of the nervous system, including those primitive reflexes concerned with the primitive emotions of the thalamo-striate brain of lower animal forms. In mammals, therefore, all the primitive emotions concerned with sex, instinct, the struggle for existence, and so on, pass through the infra-granular cortex instead of through the thalamo-striate brain. In *man* there is the still further addition of the supra-granular cortex and its enormous extension in the association areas. This is the layer of educability and control, and if it be not sufficiently developed, the individual will re-act to his environment more on the level of the animal than on that of the sentient human being.

The several phases of this evolutionary process of cerebral additions and telencephalisation are so important and so instructive to the Neuro-psychologist that some of them may

well be examined in a little more detail. Commencing with the *mesencephalon or mid-brain,* in many of the lower vertebrates the mid-brain is the largest and most conspicuous part of the nervous system, and is the only brain which the animal possesses. It was primarily evolved as a primordial "Brain" for the correlation of incoming afferent impressions, and there originally terminated in it the three great and important receptor pathways of sight, hearing, and general sensibility. These, as well as all other incoming afferent impulses, were correlated in the mid-brain in order to effect the most suitable "motor" responses. As the evolutionary scale is ascended, the mid-brain becomes progressively smaller, and, in man, has become one of the smallest and least conspicuous divisions of the brain. This, of course, is due to a progressive diminution in its functional activities, many of its original functions having become shifted forwards to, first, the thalamo-striate brain, and later, to the neo-pallium of the cerebral cortex.

The *diencephalon, or interbrain,* from which the thalamus is developed, was originally evolved as a central clearing house for all incoming afferent impulses of a higher and more complex character than those of the more primitive animal forms, in which the mid-brain served this function. The primitive vertebrate condition of the diencephalon, or inter-brain, proves that the whole of this (thalamic) region has always been afferent or "sensory" in character, and has always served for the co-ordination of incoming afferent impressions. All the great afferent paths still lead into it, and its histological construction shows no "motor" neuronic cells whatsoever; therefore, in man, the thalamus, which is the chief derivative from the inter-brain, is afferent or "sensory" in character. In the primitive brains of diencephalic animals there is associated with the thalamus, a "motor" or effector corpus striatum, which is one of the first representatives of the telencephalon, or true end-brain. This corpus striatum is a primordial structure of the vertebrate brain, and in such forms as fish, where the end brain consists of a thalamus and a corpus striatum only, the latter structure represents the highest nerve centre for the correlation of "motor" impulses, that is to say, all incoming afferent impulses are passed into the thalamus, where they are co-ordinated, and are transferred thence to the corpus striatum, where the impulses are translated into "motor" or effector responses.

In lower animal forms, such as fish and reptiles, the thalamus and corpus striatum, or their evolutionary equivalents, form the only end-brain the animal possesses. As such animals are capable of displaying certain primitive emotions, such as those connected with the display of sexual emotions, fighting

for food, the struggle for existence, etc., it follows that the thalamo-striate brain is the primitive brain of the primitive emotions.

In the human being a real end-brain has been added beyond the thalamo-striate brain, and is represented by the cerebral hemisphere. To these have been transferred, by a process of telencephalisation, many of the functions of the thalamo-striate brain, together with the control over those functions. Should, however, the nerve impulses be diverted to the more primitive pathway, there will be a display of uncontrolled emotional reflexes. As regards the *thalamus* in man, it may be stated that evolution, histology and development, all prove the purely afferent or "sensory" nature of the thalamus. That clinicians have recorded cases where lesions of the thalamus have apparently been followed by disorderly movement is undoubted, but this does not prove that the thalamus is "motor" in function. It merely indicates that the lesion in the thalamus has cut some portion of the thalamo-striate neuronic arcs, and so removed from the striate body the only control exercised over it, as it will be remembered that the corpus striatum has no direct connections with the cerebral cortex at all. In man, cortical control over the corpus striatum is only exercised indirectly through the thalamus. There is, on the other hand, a large amount of clinical evidence to show the afferent character of the thalamus, thalamic lesions being frequently followed by disorderly emotional displays, such as forced laughing or crying, automatic screaming, athetosis, and so on. In such conditions nerve impulses are, quite obviously passing over wrong, or more primitive, reflex arcs, over which, as the result of disease, cortical control has been removed.

Just as the thalamus is interposed in the path of all incoming afferent impulses, so also was the corpus striatum originally interposed in the path of the outgoing primitive effector or efferent impulses; in fact, it was the original co-ordinating station for such impulses. In lower animal forms, in which, as in fish, the thalamo-striate brain alone is present, the "motor" path was continued, from the corpus striatum in the form of a basal tract, which is the primitive "motor" pathway, and constitutes the old or paleo-kinetic "motor" pathway. With the subsequent evolution of a neopallium, as in man, and the transference thereto of most of the primitive functions of the mid- and inter-brains, there is developed, in the cerebral cortex, a new co-ordinating "motor" area, the Rolandic "motor" area, and a new "motor" pathway, the pyramidal tracts, or the neo-kinetic "motor" pathway. Under these conditions the corpus striatum of man becomes reduced

to an agency for "the production and control of automatic associated movements and the myotonic stabilisation of the muscles, which keep the muscular system in a condition adapted to the needs of the prompt performance of automatic associated movements." (Tilney and Riley.)

This evolutionary history of the corpus striatum is still further supported by the fact that, in man, the nuclei of the corpus striatum, that is, the caudate nucleus, the globus pallidus, and the putamen of the lentiform nucleus, have no direct connections with the cerebral cortex whatsoever. Cortical control is only exerted indirectly through the cortico-thalamic fibres, the thalamus, and the thalamo-striate connections. Clinical observation on the conditions of disease in these nuclei also supports the evolutionary history.

If such be the evolutionary history of the thalamo-striate brain (and as it fits in with all the known facts, there seems no reasonable ground for doubt), there emerges the fact that it is the primitive brain of the primitive animal emotions. There is also afforded a perfectly effective neuro-psychological explanation of the occurrence of many forms of hysteria, neurasthenia, psycho-neuroses, and other disordered primitive emotional conditions. In such cases it is a reasonable inference that afferent impulses are passing through the more primitive thalamo-striate pathway, without the intervention of the cerebral cortex. The cortex is, as it were, cut out of the neuronic arc, and hence the disordered movement, lack of control, and the exaggerated emotional conditions.

The far-reaching influence of this transference of neuronic reflex pathways concerned in the display of the more primitive emotions, from the primitive thalamo-striate brain to the more recently evolved cerebral cortex, can hardly be over-estimated. The emotions of fear, of sex, of animal instincts, as well as many other primitive emotions may retain, in the human being, the more primitive pathways through the thalamo-striate brain, or the infra-granular cortex, and, if so, especially when associated with a badly developed controlling supra-granular cortex, may result in such pronounced pathological behaviour as to become a menace to others, and a cause of disease, crime and prostitution. That some "psychic processes, representing a certain degree of consciousness, may be carried on by the thalamus independent of the cerebral cortex is undoubted." (Tilney and Riley.)

It has already been seen that one of the first evolutionary developments from the telencephalon is the corpus striatum. With the advent of the mammals, there is evolved a neo-pallium, or brain mantle, which is the true organ of "intelligence." This, as will be seen later, is built up on an infra-

granular basis, and, in man, a considerable addition is made in the form of a supra-granular cortex with the presence of association areas.

The *telencephalon, or final end-brain,* from which the cerebral hemispheres are developed, is the most recent evolutionary addition to the central nervous system, and to it many of the original functions of the mid- and inter-brains have been transferred. A progressive increase in the size and complexity of the brain is a noticeable and striking feature with evolutionary progress from fish to amphibia, and thence to the reptiles, birds, mammals and man, in the last of which the brain has attained its highest development.

The *human brain differs from that of all other animals* in its large size, being from two and a half to three times larger than in any other animal; in the complexity of the fissuring of its surface, which increases the number of its contained neurones; in the possession of large psychic areas, termed association areas, which again increase the number of neurones. and are hardly present at all in any other animal; in the addition to the external part of the cerebral cortex of a supra-granular layer, which again increases the number of neurones. All these successive evolutionary additions to the true end-brain have raised the number of cortical neurones to about 9250 millions, a number immensely in excess of that possessed by any other animal.

As a result of these successive increases in size, prominence and complexity, and the consequent increase in the number and complexity of the neuronic reflex arcs, the brain has gradually become transformed, from an organ for the translation of physical phenomena and their correlation, into the implement of the human mind. The structural process by which this has been accomplished is, however, always the same. It consists in the provision of additional neurones and their grouping together into neuronic reflex arcs of an ever-increasing complexity.

The great *association areas* of the human brain are its specially characteristic features. In no other animal do they occur to anything like the same extent as in man. Hence the impossibility of teaching any animal, other than man, to speak. There can be no doubt that they are functionally concerned with the higher psychic phenomena of the human brain and are linked up with all the receptor and effector areas of the cortex by association fibres; that is, axons of neurones. The human cortex differs, therefore, from that of other animals, in being broadly divisible into two great functional portions, of very unequal areas, physical and psychic, the former being present in most of the lower animals.

As regards their construction, it is important to note that the psychic association areas of the human brain do not differ in general structure from the physical portions of the cortex. They are composed of neuronic reflex arcs, with, however, an enormous number of internuncial neurones, interpolated between the limbs of the arcs. No matter what the function, the structure is always the neuronic arc in some more or less complex form.

If the individual be not educated, or only imperfectly so, many of the association neurones will not myelinate, and will not, therefore, be capable of functioning. The psychological behaviour, that is, the neurological re-action to stimuli, of such individuals will be quite different from that of normally educated persons with a sufficiency of medullated association neurones.

With the advent of the *supra-granular layer* of the cerebral cortex the channels for reflex cortical neuronic arcs are enormously increased. It is not improbable that the internuncial neurones—the dispersal or storage stations—are here represented by the short Golgi cells, as well as by the cells of Martinotti and Cajal. Short neurones are present in enormous numbers in the cortices of the cerebellum and cerebrum, but are almost absent in the spinal cord. It is the presence of these cells which produces the appearance of a granular layer in the cortex, and enables modern investigators to subdivide it into layers of cells, lying superficial (supra-granular) and deep (infra-granular) thereto. By means of these short "granular" neurones nerve impulses are dispersed all over the cortex in both vertical and horizontal planes. There is thus reached the important conclusion that the phenomena of mind are solely due to a multiplicity of neuronic arcs of great complexity, and that a diminution of such arcs, from any cause whatsoever, will be attended by a diminution in the display of "intelligent" action, that is, the psychological behaviour of the individual will vary with the number of the neurones. Cerebral localisation, as ordinarily understood in Medicine, is, therefore, only an approximation to the truth. The post-central gyrus, for example, is not so much a terminal station as a central shunting station.

Development, evolution, histology and pathology, all seem to tell the same story, namely, that the central nervous system is a complex of neuronic reflex arcs, the chief stations of which (see Figure 4) are as follows:—

1. The simple reflexes of re-action to physical stimuli with their centres in the spinal cord, and typically exemplified in the segments of the earthworm and the knee jerk of man.

2. The reflexes of the vital functions of life, such as breath-

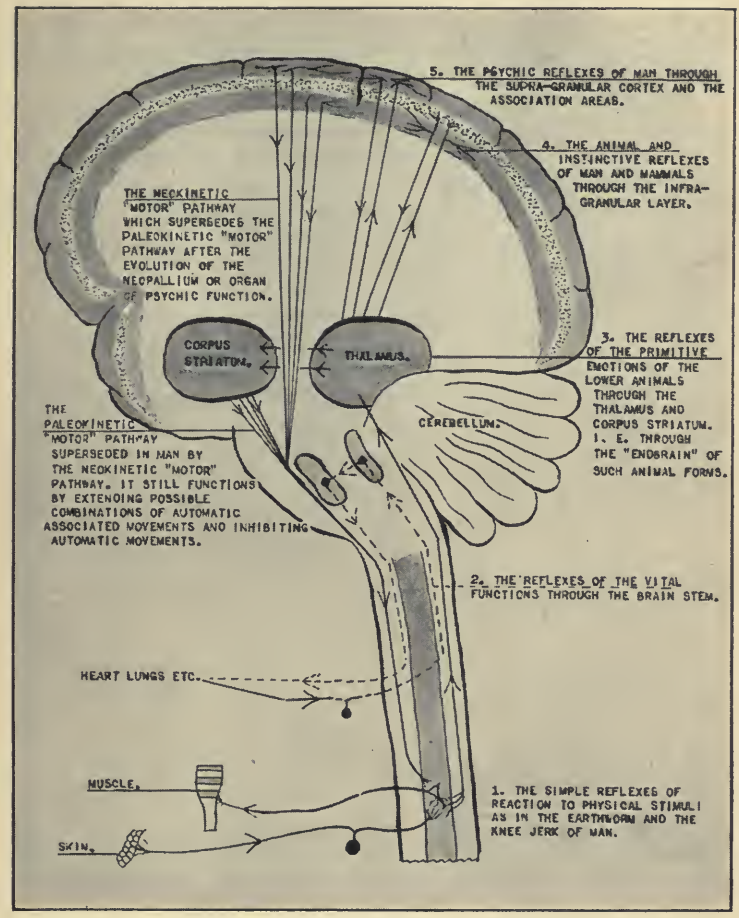

5. THE PSYCHIC REFLEXES OF MAN THROUGH THE SUPRA-GRANULAR CORTEX AND THE ASSOCIATION AREAS.
4. THE ANIMAL AND INSTINCTIVE REFLEXES OF MAN AND MAMMALS THROUGH THE INFRA-GRANULAR LAYER.
THE NEOKINETIC "MOTOR" PATHWAY WHICH SUPERSEDES THE PALEOKINETIC "MOTOR" PATHWAY AFTER THE EVOLUTION OF THE NEOPALLIUM OR ORGAN OF PSYCHIC FUNCTION.
CORPUS STRIATUM.
THALAMUS.
3. THE REFLEXES OF THE PRIMITIVE EMOTIONS OF THE LOWER ANIMALS THROUGH THE THALAMUS AND CORPUS STRIATUM. I. E. THROUGH THE "ENDBRAIN" OF SUCH ANIMAL FORMS.
CEREBELLUM.
THE PALEOKINETIC "MOTOR" PATHWAY SUPERSEDED IN MAN BY THE NEOKINETIC "MOTOR" PATHWAY. IT STILL FUNCTIONS BY EXTENDING POSSIBLE COMBINATIONS OF AUTOMATIC ASSOCIATED MOVEMENTS AND INHIBITING AUTOMATIC MOVEMENTS.
2. THE REFLEXES OF THE VITAL FUNCTIONS THROUGH THE BRAIN STEM.
HEART LUNGS ETC.
MUSCLE.
SKIN.
1. THE SIMPLE REFLEXES OF REACTION TO PHYSICAL STIMULI AS IN THE EARTHWORM AND THE KNEE JERK OF MAN.

FIGURE 4.

A diagram designed to show the five main sites of neuronic reflex arcs in the central nervous system. (Berry.)

ing and the control of the heart beat, with their centres in the brain stem.

3. The reflexes of the primitive emotions of the lower animals through the thalamus and the corpus striatum, that is, through the end-brain of such animal forms.

4. The animal and instinctive reflexes of mammals and man through the infra-granular cortex of the neopallium.

5. The psychic reflexes of man through the supra-granular cortex of the neopallium and the association areas.

That this conception of the phenomena of "mind," as being entirely dependent on neuronic construction and association, is correct, is fully borne out by everything that evolution, biology, embryology, and clinical medicine have to teach us.

LECTURE 2.—BRAIN GROWTH AND EDUCATION.

The President of the British Medical Association, Victorian Branch, Mr. Basil Kilvington, M.S., presiding.

Mr. President, Mr. Dean, Ladies and Gentlemen—

Every human individual passes, during the pre- and post-natal stages of growth, through the developmental and evolutionary phases sketched out in the first lecture. He reproduces in his own growth the evolutionary stages of his ancestors.

At birth the newborn infant is little more than a splanchnic, or visceral, series of hunger reflexes. With growth and medullation of neurones there follow the acquisition of certain physical properties, such as sight, hearing, smell, taste, touch, and so on, all of which increase the range of consciousness. Simultaneously with the acquisition of these properties, many visceral or splanchnic afferent impressions are added which inform the individual of the state of his own body. With the acquisition of speech and the rudiments of education still more neurones assume their function, and the range of consciousness is still further increased, and so on, till the full complement of "sensory" or afferent impressions is acquired—always provided there be no arrest of neuronic development. As all of these involve neuronic reflex paths and a general synchronisation in the cerebral cortex, and as these afferent impulses differ materially in different individuals, it follows that no two individuals have exactly the same "mind" or the same outlook on life.

That the recently acquired telencephalon or end-brain controls individual behaviour, that is, the re-action to the environment, is undoubted, and that these re-actions depend entirely on the number and connections of the neurones is equally certain. The cerebral cortex has, therefore, assumed control over the whole central nervous system of man. To that cortex attention may now be directed.

It has long been known that the grey cerebral cortex is composed, histologically, of a laminated arrangement of variously shaped nerve cells, with their axons and dendrons, embedded in neuroglia. Within more recent years it has been shown that, even with the naked eye, white lines can be seen in the cerebral cortex, which thus presents a striated or laminated appearance, and Elliot Smith has demonstrated the further fact that the arrangements of these white lines differ, apparently in accordance with the different functions

of the various parts of the cortex. These white lines are produced by bundles of axons running in the cortex, parallel with the surface, and are variously known as lines of Baillarger, or, in the visual area, as the stria of Gennari. Within these white lines there are but few nerve cells, but between the white lines the cells are numerous, and the axons relatively few, hence the microscopic and naked eye appearances of different parts of the cerebral cortex are quite different in detail, and these details of structural difference are undoubtedly concerned with differences in function. It is further known that in parts of the cortex there occur very short neurones, which are so numerous in certain places as to confer a granular appearance on the particular portion of the cortex in which they occur. This granular appearance is particularly well seen, for example, in the "sensory" post-central cortex, where it constitutes the fifth layer of the histologist. This granular layer is the modern key to the cortex, because the recent striking work of Sir Frederick Mott, Dr. J. S. Bolton and Dr. G. A. Watson has shown that it originally constituted the primitive external layer of the cortex, or, expressed differently, the mammalian cerebral cortex is built up on an infra-granular basis, the supra-granular layer being a more recent evolutionary addition. Deep to this granular layer are a number of pyramidal and other cells, which may be collectively grouped together as the infra-granular layer. Superficial to it are again pyramidal and other cells, which form the supra-granular layer. Expressed in as simple terms as possible, the cerebral cortex of mammals and man may be divided into three great layers, which are, from the surface inwards—the supra-granular layer, the granular layer, and the infra-granular layer. Within these occur the white lines already referred to.

As regards the *functions of these three great layers* of cortical cells, the views of the distinguished neuro-pathologists mentioned may be summarised, at least, as I understand them, as follows:—

The most important portion of the cerebral cortex is the *supra-granular layer*. It is the layer which most distinguishes the human from the mammalian cortex. It undergoes degenerative changes in certain types of dementia, and is imperfectly developed in cases of feeble-mindedness. It subserves the higher thought processes, and is, therefore, the layer through which education largely works. It is the layer which is last developed, having at birth attained only 50 per cent. of its ultimate adult thickness.

The *granular layer* is believed to subserve "sensory" functions, because within, or very close to, this layer many afferent

axons have their terminations, and thus produce one of the white lines referred to. Further, the granular layer attains its greatest development in those portions of the cortex to which are ascribed "sensory" functions. At birth this layer has attained 75 per cent. of its ultimate adult thickness. Through this layer all afferent axons proceeding from all organs of sense are enabled to serve as feeding inlets from the external physical and internal bodily worlds to the brain as a whole. Hence the development of the supra-granular layer is largely dependent upon the activity of the cells of the granular layer. If this stimulation be cut off in any direction, as, for instance, in congenital blindness or deafness, a diminished brain growth results. (See Berry and Porteus' "Intelligence and Social Valuation".) As the granular layer is composed almost exclusively of very short neurones of the Golgi second type, it is clear that these neurones are to be regarded as internuncial neurones, interposed between the afferent neurones, as one of the limbs of the neuronic reflex arcs, and efferent projection, association, and commissural fibres, as the other limbs. Such cells are, therefore, clearly radiating stations for nerve impulses, and disperse the same all over the cerebral cortex.

The *infra-granular layer* is relatively and absolutely as well developed in the higher mammals as in man, and is equally well developed in the feeble-minded as in the normal individual. It is supposed to be "concerned especially with the associations necessary for the performance of the instinctive activities, that is, all those which are innate or require for their fulfilment no experience or education. These form the basis of many complex actions necessary for the preservation of the individual and the species, such as the seeking of appropriate shelter and protection, the hunting of food—each after his own kind—and the quest of the opposite sex." (Watson.) Shortly after birth the infra-granular layer has attained 82 per cent. of its ultimate adult thickness. Judgment, commonsense, reason, as evidenced in behaviour —in a word, social efficiency—are dependent on the control of the activities of the infra-granular layer by the supra-granular.

If this brief summary of the views of the writers quoted be compared with Figure 5, in which the structure and functions of these layers of the cerebral cortex are diagrammatically displayed, the reader will be furnished with much food for thought, and will not improbably find a key to many problems which are quite erroneously thought to be "psychological complexes," incapable of solution except by phychoanalytical methods.

Although the *physiology of sleep* is not altogether understood, it is clear that all nerve cells are not affected by sleep. Those in the medulla which are concerned with the vital phenomena of respiration and the circulation never go to sleep during the whole of life, though, naturally, their activity is diminished during sleep. Sleep, apparently, first affects the outermost layers of cells in the supra-granular layer, and gradually works down to the deeper-lying cells, and may ultimately involve many, if not all, of the cells of the infra-granular layer. It thus follows that during sleep the higher psychic functions of the human brain are first abrogated, and the individual passes from complete consciousness through the various stages of semi-consciousness, sub-consciousness and unconsciousness, according as to the number and depth of brain cells affected. As the supra-granular layer "goes to sleep," the control over the infra-granular layer is removed, and hence our dreams may run riot. If afferent impulses from a distended ovary or testicle are being conveyed to the uncontrolled infra-granular layer, the dreams may be of a sexual or erotic character. If from a distended stomach, their nature will again be different.

These modern views on the neuro-psychological structure and functions of the cerebral cortex are, again, particularly well exemplified by the *administration of a poison, such as alcohol.* In its early stages alcohol stimulates the supra-granular layer, and produces a temporary and evanescent phase of psychic brilliance. In continued doses it next poisons the supra-granular layer, and, with the control removed from the infra-granular layer, the functions of that layer assert themselves, and the sexual appetite manifests itself. As this layer gradually becomes poisoned, the individual sinks into a state of coma, because all his brain cells are becoming poisoned, and are ceasing to function. Eventually death is produced.

It is further known that in chronic alcoholics the supra-granular layer is not only reduced in thickness, but its pyramidal and other cells are reduced in number, and are replaced by simple fibrous thickening. This, again, means a diminished control over the animal calls from the infra-granular layer, and a vicious circle is established, wherein the unfortunate individual destroys his controlling supra-granular layer, and the more he does so, the more he succumbs to the instinctive activities of his infra-granular layer.

Education, on the other hand, particularly when continued into adult life—and by education is here meant any process which involves the psychic or association areas, and not merely some small physical area, such as, say, the "motor" area con-

cerned in the mechanical process of hammering nails in boots —apparently stimulates many short association neurones in the supra-granular layer to myelinate, that is, to function. Without such exercise, they remain undeveloped, and, all other things being equal, such brains will tend to be slightly smaller. Of the general truth of this statement there is much corroborative evidence.

Bolton has quite definitely shown that the supra-granular layer of the cerebral cortex is underdeveloped to different degrees, according to the mental capacity of the individual, in persons exhibiting various grades of mental subevolution, and that it undergoes degrees of retrogression, which correspond to the amount of dementia existing in cases which permanently suffer from diminution or loss of their mental power. The same authority has also shown that the supra-granular layer is the last layer of the cortex to commence to develop, the last to attain maturity, and consequently is the first to undergo natural retrogression, because, from the evolutionary standpoint, having been recently added, it is in a state of instability. Lastly, the supra-granular layer is the only cell layer of the cerebral cortex which definitely varies in measurable depth in normal brains.

The very deep significance of this recent work on the cerebral cortex does not, as yet, seem to have been realised or assimilated by either psychologists or the medical profession, but of its truth the writer has no doubt whatsoever. Some years ago Mr. Porteus and myself commenced a clinical investigation amongst feeble-minded children, and we had not proceeded very far before the full import of the findings of Mott, Bolton and Watson impressed themselves very forcibly upon us. This was, indeed, so much so, that we decided to scrap the observations we had accumulated, and commence the work anew with a constant eye on the application of this cortical work to the living child. In all, upwards of 10,000 normal children and young adults were examined.

It has long been known that the size of head and cubic capacity of brain tend, on the average, to be larger in educated classes than in uneducated classes, but that there is no ascertainable correlation whatsoever between size of head and intelligence in the individual at any age or in any walk of life. It has also long been known that education of the nature previously mentioned has a slight, but appreciable, influence in stimulating both head and brain growth. Of the proof of this, the classical work of Dr. Venn and Sir Francis Galton, published more than 30 years ago, may suffice. Dr. Venn examined 1000 Cambridge students, who fell into three groups—(A.) First-class men in any tripos

FIGURE 5.

A diagram of the structure and functions of the cerebral cortex. (Berry.)

On the left are the eight histological layers of the "sensory" post-central gyrus.

Next follows a diagrammatic representation of the nerve cells themselves, together with examples of neuronic reflex arcs through this portion of the cortex. The mode of formation of the white lines of Baillarger is indicated, as is also the fact that, in the cerebral cortex, the intermediate or inter-nuncial neurones are extremely numerous, and comprise the Golgi second type of neurone, and the less numerous cells of Martinotti and Cajal. These cortical inter-nuncial neurones, which are only found in large numbers in the cerebral and cerebellar cortices, may be regarded as dispersal stations, or possibly as storage cell stations.

The next two columns represent two different schools of nomenclature, both based on the fact that the mammalian cerebral cortex is built up on an "infra-granular" basis.

The last column gives the functions, according to Mott, Bolton, and Watson, of the two cortical brains of man, namely, the infra-granular brain, and the supra-granular brain, the two being separated by a "granular" layer of afferent terminations.

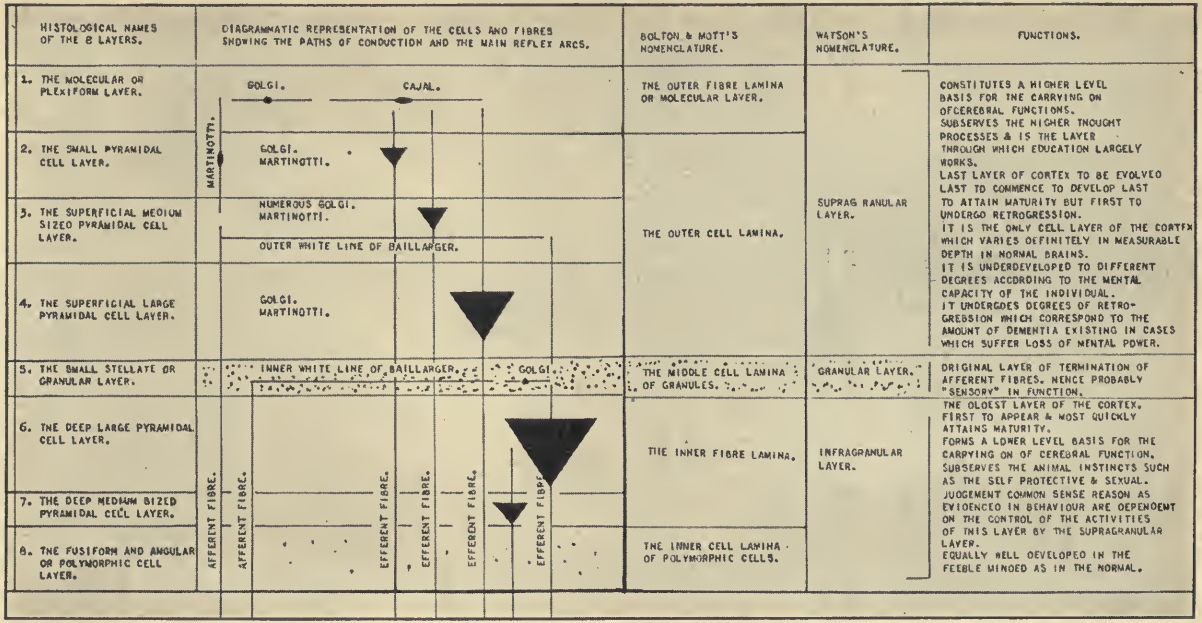

HISTOLOGICAL NAMES OF THE 8 LAYERS.
DIAGRAMMATIC REPRESENTATION OF THE CELLS AND FIBRES SHOWING THE PATHS OF CONDUCTION AND THE MAIN REFLEX ARCS.
BOLTON & MOTT'S NOMENCLATURE.
WATSON'S NOMENCLATURE.
FUNCTIONS.
1. THE MOLECULAR OR PLEXIFORM LAYER.
2. THE SMALL PYRAMIDAL CELL LAYER.
3. THE SUPERFICIAL MEDIUM SIZED PYRAMIDAL CELL LAYER.
4. THE SUPERFICIAL LARGE PYRAMIDAL CELL LAYER.
5. THE SMALL STELLATE OR GRANULAR LAYER.
6. THE DEEP LARGE PYRAMIDAL CELL LAYER.
7. THE DEEP MEDIUM SIZED PYRAMIDAL CELL LAYER.
8. THE FUSIFORM AND ANGULAR OR POLYMORPHIC CELL LAYER.
GOLGI.
CAJAL.
MARTINOTTI.
GOLGI. MARTINOTTI.
NUMEROUS GOLGI. MARTINOTTI.
OUTER WHITE LINE OF BAILLARGER.
GOLGI. MARTINOTTI.
INNER WHITE LINE OF BAILLARGER.
GOLGI
AFFERENT FIBRE.
AFFERENT FIBRE.
EFFERENT FIBRE.
EFFERENT FIBRE.
EFFERENT FIBRE.
EFFERENT FIBRE.
THE OUTER FIBRE LAMINA OR MOLECULAR LAYER.
THE OUTER CELL LAMINA.
THE MIDDLE CELL LAMINA OF GRANULES.
THE INNER FIBRE LAMINA.
THE INNER CELL LAMINA OF POLYMORPHIC CELLS.
SUPRAGRANULAR LAYER.
GRANULAR LAYER.
INFRAGRANULAR LAYER.
CONSTITUTES A HIGHER LEVEL BASIS FOR THE CARRYING ON OF CEREBRAL FUNCTIONS. SUBSERVES THE HIGHER THOUGHT PROCESSES & IS THE LAYER THROUGH WHICH EDUCATION LARGELY WORKS. LAST LAYER OF CORTEX TO BE EVOLVED LAST TO COMMENCE TO DEVELOP LAST TO ATTAIN MATURITY BUT FIRST TO UNDERGO RETROGRESSION. IT IS THE ONLY CELL LAYER OF THE CORTEX WHICH VARIES DEFINITELY IN MEASURABLE DEPTH IN NORMAL BRAINS. IT IS UNDERDEVELOPED TO DIFFERENT DEGREES ACCORDING TO THE MENTAL CAPACITY OF THE INDIVIDUAL. IT UNDERGOES DEGREES OF RETROGRESSION WHICH CORRESPOND TO THE AMOUNT OF DEMENTIA EXISTING IN CASES WHICH SUFFER LOSS OF MENTAL POWER.
ORIGINAL LAYER OF TERMINATION OF AFFERENT FIBRES. HENCE PROBABLY "SENSORY" IN FUNCTION.
THE OLDEST LAYER OF THE CORTEX. FIRST TO APPEAR & MOST QUICKLY ATTAINS MATURITY. FORMS A LOWER LEVEL BASIS FOR THE CARRYING ON OF CEREBRAL FUNCTION. SUBSERVES THE ANIMAL INSTINCTS SUCH AS THE SELF PROTECTIVE & SEXUAL. JUDGEMENT COMMON SENSE REASON AS EVIDENCED IN BEHAVIOUR ARE DEPENDENT ON THE CONTROL OF THE ACTIVITIES OF THIS LAYER BY THE SUPRAGRANULAR LAYER. EQUALLY WELL DEVELOPED IN THE FEEBLE MINDED AS IN THE NORMAL.

FIGURE 5.

A diagram of the structure and functions of the cerebral cortex. (Berry.)

examination, or one who was a scholar of his college; (B.) All the remaining honour men; (C.) Candidates for ordinary degrees, that is, pollmen or passmen. It was found that at 19 years of age Class A. had a brain 5 per cent. larger than Class C. At the end of their University career, Class A's. brain had been increased by 3 per cent., whilst Class C's. brain had increased by 6 per cent. "From all this," says Sir Francis Galton, "follow four conclusions:—

"1. Although it is pretty well ascertained that, in the masses of the population, the brain ceases to grow after the age of 19, or even earlier"—and more modern investigation shows that it is earlier—"it is by no means so with University students.

"2. That men who obtain high honours have had considerably larger brains than others at the age of 19.

"3. That they have had larger brains than others, but not to the same extent, at the age of 25—in fact, their predominance is by that time diminished to the half of what it was.

"4. Consequently 'high honour' men are presumably, as a class, both more precocious and more gifted throughout than any others. We must, therefore, look upon eminent University success as a fortunate combination of these two helpful conditions."

The general effects of education on brain growth, as deduced by Galton, have been amply confirmed by many other subsequent investigators. But recently there has emerged the striking and singularly important fact that it is chiefly the all-important supra-granular layer of the cortex which is so affected by post-pubescent education. As this is one of the most important results of the investigation recently undertaken by Mr. Porteus and myself, it will be necessary to refer to that work in some detail in order to demonstrate the point, and to show that, in a few cases, it is possible, even now, and with the crude physical methods at our disposal, to determine, on the living subject, the probable state of development of the cortical layers of the child's brain, and hence, provided those findings agree with other avenues of approach, to make a reasonably accurate forecast as to how the child will react to his environment.

That mental capacity depends on brain capacity, that is, on neurones, is undoubted, as is also the fact that striking deviation from the normal tends to be associated with mental abnormality. It is, however, clearly impossible to determine the frontiers of abnormality until the normal be known. As the cubic capacity of brain of a normal living boy or girl, at the different ages of life, was quite unknown, we were compelled,

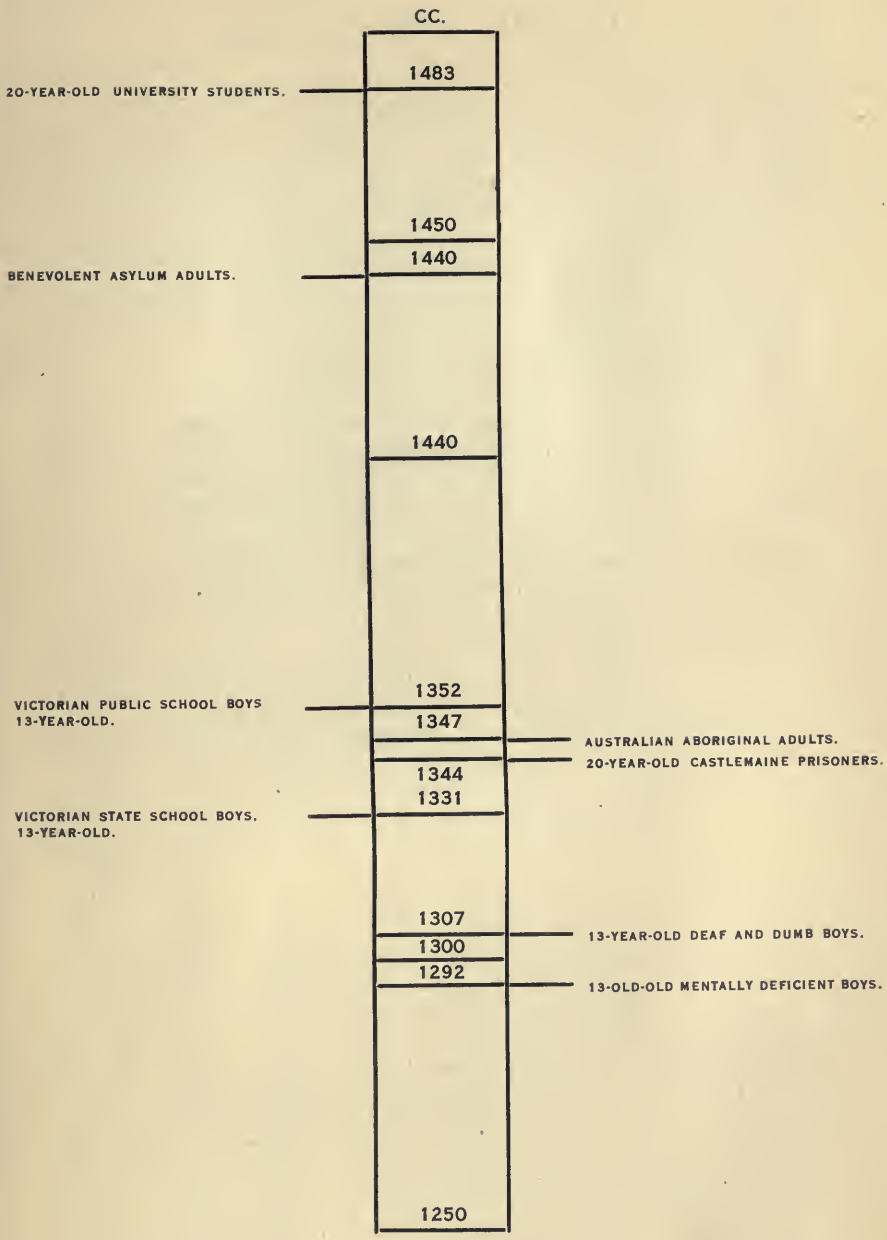


FIGURE 6.

A chart, drawn to scale, illustrating the relative positions of the normal, abnormal, and aboriginal groups of cases as regards the cubic capacity of brain. (Berry.)

before anything else could be done, to undertake an enquiry of considerable magnitude, which had, as its first and immediate object, the determination of the amount of cubic capacity of brain which the average normal boy and girl should possess at each year of educational life. The second object was the determination of the frontiers of possible cerebral abnormality, and the third and last object, the correlation of the results, if any, with the principles of modern neuro-psychology. For the purposes of these objects, there were examined, including control cases, 6700 males and 2717 females.

The male cases may be set forth as follows:—

A. Normal cases—	
1. Victorian State School boys, between the ages of 6 and 15 years	4177
2. Victorian Public School boys and Melbourne University students, from the ages of 6 to 30 years	2104
3. Adult inmates of the Melbourne Benevolent Asylum for the Aged and Infirm	217
B. Abnormal Cases (Controls)—	
4. Mentally deficient children, of various ages	60
5. Victorian Deaf and Dumb Institute	53
6. Castlemaine Reformatory for Indeterminate Sentence criminals	25
C. Primitive Race (Evolutionary Controls)—	
7. Australian aboriginal natives from the Northern Territory	64
Total	6700

It will probably occur to the critic—just as it did to us—that if the scientific principles upon which this work is based are really correct, namely, that mind is dependent on numbers of neurones, and that the greater the number of neurones the larger the brain and the greater the intellect, it should be demonstrable in the generalised average results of the cubic capacity of brain of the above widely separated class groups; and that, if it be not so demonstrable, the whole of the hypothesis falls to the ground and is worthless. This is legitimate and necessary criticism, and is very strikingly answered by Figure 6. Compare, for example, the relative cerebral development of the known mentally deficient and deaf and dumb boys of the 13th year of life with normal boys of the same age, or the relative development of the 20-year-old criminal with the University student of like age. Observe the lowly place taken by the evolutionary backward

Australian aboriginal, who is seen only to have the cerebral development of the 13-year-old schoolboy. Notice, too, that those adults who, as the result of a thriftless and shiftless life, have had to end their days in a benevolent asylum, are altogether below the standard of an educated youth of 20 years. The whole graph is a most striking demonstration of the truth of the principles on which this work is based.

As regards the first object of our investigation—namely, *the determination of the amount of cubic capacity of brain which the average normal boy and girl should possess at every year of educational life*—we have fully set forth our results in the monograph already referred to; here, therefore, it will suffice to give these results in a general way, and to discuss their significance from the standpoint of the influence of education on brain growth.

The following table displays our results for the true means of the cubic capacity of brain of boys and girls, from birth onwards, the relative percentage volume of brain, and the periodical increments in brain volume.

	Girls			Boys			
Year of Life	Cubic Capacity of Brain in C.C.	Percentage Volume of Brain	Periodical Increment of Brain Growth	Cubic Capacity of Brain in C.C.	Percentage Volume of Brain	Periodical Increment of Brain Growth	Phase of Sexual Life
Birth	333	25.0		371	25.0		
1st	849	63.7		945	63.7		
2nd	966	72.5		1075	72.5		
3rd	1035	77.6		1151	77.6		
4th	1066	80.0		1186	80.0		
5th	1096	82.2		1206	81.3		Pre-Pubescent Phase
6th	1121	84.1		1225	82.6		
7th	1146	85.6		1244	83.9		
8th	1162	87.1		1264	85.2		
9th	1173	88.0		1283	86.5		
10th	1199	89.9		1301	87.7		
11th	1217	91.3	91.3	1317	88.8	88.8	
12th	1226	91.9	0.6	1326	89.4	0.6	Resting Phase
13th	1257	94.3		1351	91.1		Pubescent Phase
14th	1271	95.3	3.4	1358	91.6	2.2	
15th	1279	95.9		1378	92.9		
16th	1304	97.8		1402	94.5		
17th	1305	97.9		1422	95.9		Post-Pubescent Phase
18th	1307	98.0		1447	97.6		
19th	1324	99.3		1463	98.6		
20-30	1333	100.0	4.7	1483	100.0	8.4	

Note.—In the first four years of life the figures are as calculated. In all the remainder they are as actually observed on the living subject.

This table would appear to show that if the education of the child's association areas is continued on into the third decade of life, that is, into the University period, brain growth proceeds continuously, and is naturally divisible into four periods.

There is, first, a pre-pubescent period, which covers, roughly, the first eleven years of life. During this period brain growth proceeds more rapidly in girls than in boys, the respective percentages of total brain volume being 91.3 per cent. and 88.8 per cent.

Secondly, there is a resting phase of one year—the twelfth year—immediately preceding the onset of puberty. During this year brain growth is almost stationary in both sexes, and only increases by 0.6 per cent. in both boys and girls.

Thirdly, there follows a period of two years—the thirteenth and fourteenth years—coincident with puberty, during which the brain increases by 3.4 per cent. in girls and 2.2 per cent. in boys.

Lastly, comes the fourth period of six or more years, which takes the individual into adult life. This is a post-pubescent period, during which the brain should complete its growth, but does not always do so. If completed, it appears to increase by 4.7 per cent. in girls, and 8.4 per cent. in boys.

This study of the actual brain growth of the living boy and girl is interesting, inasmuch as it fully proves the earlier precocity of the girl, and coincides with many other allied observations.

It is extremely unfortunate that, as Sir Harry Johnston remarked in 1916, the masses, very unfortunately, leave school more or less when they are twelve, and are not compelled, as they should be, to attend continuation classes afterwards up to the age of sixteen, because they lose the stimulus to this post-pubescent brain growth, and there is irrefutable evidence, both from our own investigations, as also from many other sources, that in about 15 per cent. of a population brain growth ceases at, or about, the level of the 14th year; that is to say, the all-important supra-granular layer of the cerebral cortex does not complete its development. As this means that there will not be full control over the animal calls of the infra-granular layer, such individuals may, given the suitable environment, develop into criminals, prostitutes, and social inefficients. All the evidence goes to show that brain centres which are little used do not develop normally, and consequently the educated classes, that is, those who are constantly using their psychic or association areas, as opposed to the physical areas of the brain, have the largest brains, and in them, too, the process of senescence of the supra-granular layer is delayed.

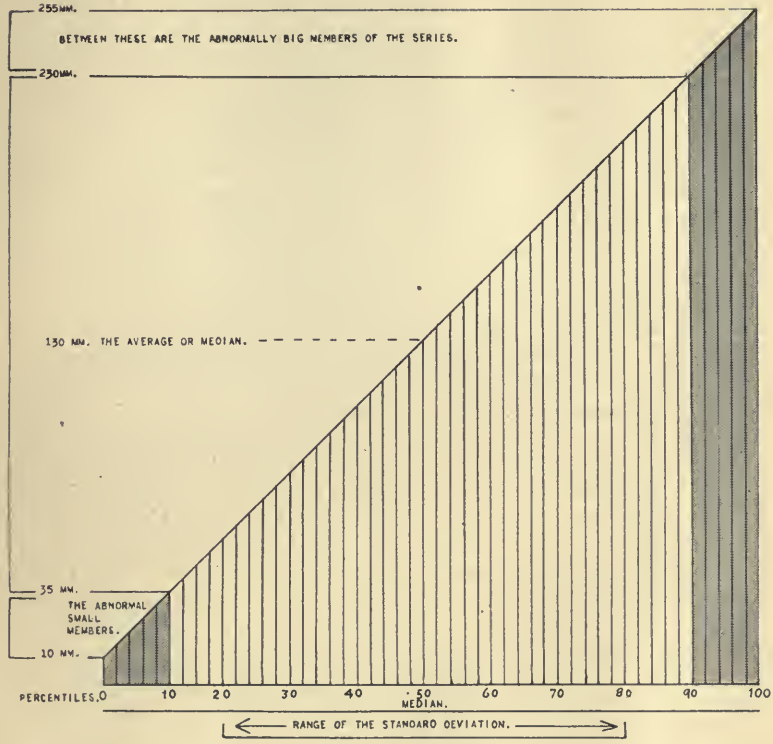

255MM.
BETWEEN THESE ARE THE ABNORMALLY BIG MEMBERS OF THE SERIES.
230MM.
130 MM. THE AVERAGE OR MEDIAN.
35 MM.
THE ABNORMAL SMALL MEMBERS.
10 MM.
PERCENTILES. 0 10 20 30 40 50 60 70 80 90 100
MEDIAN.
RANGE OF THE STANDARD DEVIATION.

FIGURE 7.

A chart, to illustrate the use of a percentile table in order to determine the potential frontiers of abnormality. Those below the 10 percentile, or above the 90 percentile, may be provisionally regarded as being abnormal. (Berry.)

Having determined the mean capacity of brain which the normal living child may reasonably be expected to possess at any given period of life, we next proceeded to the second of our objects, namely, the *determination of the range of variation from the mean*, and the ascertainment, if possible, how far extremes from the mean are to be regarded as abnormal. We were, indeed, very early impressed with the necessity of this enquiry, because it soon became obvious that many children of the same chronological age and the same social standing departed very profoundly from these means. For the purposes of this portion of our enquiry, we made use of the well-known statistical standard deviation, in the first place, and, later on, of the almost equally well-known method of percentiles. This last method was described by me in the *British Medical Journal* of July 14, 1921, and hence it will suffice to introduce the graph shown in Figure 7, which shows very clearly exactly what is meant, and the great utility of employing percentiles in order to determine how far an individual departs from the average or mean of his class. As applied by us to head size, these percentiles for cubic capacity of brain merely gave us the extremely small-headed at one end of the scale, and the extremely big-headed at the other end of the scale. Apart from the scientific accuracy of this observation, it told us, as yet, nothing else whatsoever. We then proceeded to submit random groups of children whose brain capacity fell below the 10 percentile, or above the 90 percentile, to a searching series of mental and other standardised tests. From this group of 200 children there resulted the significant facts that, of the small-headed, 50 per cent. were at feeble-minded levels, 45 per cent. were of average intelligence, and only 5 per cent. were of supernormal intelligence. Of the big-headed, on the other hand, only 14 per cent. were at feeble-minded levels, 61 per cent. were apparently normal, but 25 per cent. were distinctly of supernormal intelligence. Expressed still more simply, one in every two of the small-headed was of feeble-minded intelligence, and of the big-headed one in every four was of supernormal intellect. Considering the present crudity of the methods at our disposal for the examination of the brain on the living subject, these figures are quite surprising in their general agreement with the scientific principles involved, and with other facts which have resulted from the mental testing of many thousands of school children by Terman and other observers.

The last point with which we were concerned was, *how far did these facts fit in, if at all, with the work of Mott, Bolton and Watson, on the cerebral cortex?* To appreciate this point

and its very deep significance, it is necessary to be familiar with the mode and rate of development of the several layers of the cerebral cortex, as determined by these observers, and to add on to that the facts which have since emerged from our work, as to the rate of brain growth on the living child from birth onwards. This may be done by combining the two consecutive series of results into one table, as follows:—

ONTOGENETIC DEVELOPMENT OF THE CORTICAL LAYERS OF THE BRAIN.

Period of Life.	"Infra-granular" Layer.	"Supra-granular" Layer.	Volume of Brain.
4th month foetus	Undifferentiated neuroblasts	Superficial indifferent cells	
6th month foetus	75 per cent. of adult thickness	25 per cent. of adult thickness	
Birth	Has remained almost stationary	50 per cent. of adult thickness	25 per cent. total volume
6 weeks old	82 per cent. of adult thickness	60 per cent. of adult thickness	
1st birthday			63.7 per cent. total volume
2nd birthday			72.5 per cent. total volume
4th birthday			80.0 per cent. total volume
13th birthday			91.1 per cent. total volume

This table makes it clear that *post-natal brain development is chiefly associated with supra-granular cell growth.* If, therefore, the total volume of the brain is very much below what our figures show it should be at any period of life, then there is the almost certain inference that it must be the supra-granular layer which is lagging behind in development. Conversely, if the child's brain be larger than normal, particularly if correlated with other signs of intelligence, then it is an almost equally certain inference that the supra-granular layer is in excess of normal. In one-half of the small-headed (that is, in 5 per cent. of the total) and in one-quarter of the big-headed (that is, in 2.5 per cent. of the total), head measurement has afforded some approximation of the relative state of development of the cortical layers of the brain on the living subject. These figures, though necessarily small, in view of the crudity of the only available method yet known to us,

combined with the researches of Mott, Bolton and Watson, prove the great social significance of the observation.

Small though these figures may appear to be, it is singular how closely they agree with those of other observers in other fields of mental research.

Taking first the *children in whom the supra-granular layer does not attain full development,* that is, the definitely feeble-minded, Terman tells us that in every school not far from 2 per cent. of the children have a grade of intelligence, which, however long they live, will never develop beyond the average intelligence of an 11 or 12-year-old child. They may be taught a certain amount of rote learning, such as that involved in reading and simple arithmetic, but they cannot be taught to meet new conditions effectively, or to think, reason, and judge as normal persons do. These remarks of Terman would apply equally well to the children of Australian aboriginals brought up in schools with white children. After the age of puberty, consequent on the lack of development of the supra-granular layer, such children do little or no good. Continuing, Terman says—with which we agree—that every child who fails in his school work, or is in danger of failing, should be submitted to an expert physical and mental examination. Not all criminals are feeble-minded, but all feeble-minded are at least potential criminals. Every feeble-minded woman is a potential prostitute. Moral judgment, social judgment, or any other kind of higher thought process, is a function of intelligence, that is, of neuronic growth. Morality cannot flower and fruit if intelligence remain infantile. Observe how these observations coincide with the known functions of the supra- and infra-granular layers of the cerebral cortex.

No sane person would dream of entrusting his private or business affairs to children and schoolboys, and yet this is exactly what the community does with many of its affairs of State. It permits individuals of extreme backwardness—many of them not more cerebrally or mentally developed than the boy of 8, 10 or 12 years of age—to vote on problems of great and vital national importance, to impede in their younger days the effective work of the schools, to become sexual plague spots in the community, to propagate their kind in legitimate and illegitimate ways, and generally to act as a virulent social poison.

When the adult body, with its adult instincts, is coupled with the undeveloped brain and intelligence and weak inhibitory powers of a 10-year-old child, the only possible outcome, except in those cases where constant guardianship is exercised by relatives and friends, is some form of delinquency. This delinquency most usually assumes one or

other of two forms—either uncontrolled sexual or homo-sexual gratification—or some form of moral delinquency, such as thieving, lying, slander, as well as other animal instincts. Again, observe how this coincides with the known functions of the two great cortical layers of the brain.

As regards the super-intelligent child, in at least five times out of six he is of the big-headed type, and the relative number of such children is approximately as great as the number of feeble-minded. Terman's figures of a 2 per cent. incidence again agree in a most remarkable manner with our 2.5 per cent. Terman tells us that the future welfare of the country hinges, in no small degree, upon the right education of these superior children. Whether civilisation moves on and up depends most on the advances made by creative thinkers and leaders in science, politics, art, morality and religion. Moderate ability can follow or imitate, but genius must show the way. Mental tests show that super-intelligent children are very apt to be misunderstood in schools, and the degree of superiority of such children is rarely estimated by the teacher with anything like the accuracy which is possible to the trained neuro-psychologist. Teachers should, therefore, be better trained in the methods of detecting the signs of superior ability. The real danger with all such children is not over pressure, but under pressure. Unless they are given the class of work which calls forth their best efforts, they run the risk of falling into lifelong habits of submaximum efficiency.

All children of a given age are not equally advanced in a physiological sense. The number of years a child has lived is his *chronological age.* In contradistinction to this, the stage of maturity, mental, physical, or sexual, which the child has attained is his *physiological age.* Differences between chronological and physiological age may, and frequently do, persist into adult life. Hence there are many individuals with the bodies and sexual passions of adults and the brains of children. A closer investigation of the relations existing between the anatomical, physiological and mental ages is one of the urgent problems of educational hygiene. Society has, therefore, no moral right whatsoever to turn over the immature or mentally weak child to the overtaxing work of mill or factory on the mere basis of so many years lived. Still less has it the right to give votes on a mere basis of chronological age. The lack of judgment, the irresponsibility, and the mental unripeness of youth have a more material basis than the lack of experience. Developed brain cells are necessary, and a rich network of medullated nerve connections, particularly in the supra-granular layer.

Hitherto a *diagnosis of feeble-mindedness* has been largely a

matter of opinion and guesswork, or has been based almost exclusively on mental tests, such as the Binet or other well-known methods. The time has, however, arrived when greater accuracy is called for, as well as for a closer degree of correlation of the social reactions with the physical instrument itself. We have sought to combine these objects in the following method, which seems to us to be, at least, the correct lines on which diagnosis should proceed. It must also be borne in mind that this method is a combination method, and has stood the test of actual clinical application, not once, but many times.

The individual's brain capacity is first ascertained, and is compared with the percentile capacity of that of his age group.

His physical measurements of standing stature, sitting stature, and weight, are next recorded, placed in their correct percentiles, and the average of the three percentiles taken as representing his physical position relative to other children of his own age.

A similar procedure is adopted with the right grip, left grip, and vital capacity, all of which are again recorded in percentiles. It is a singular and impressive thing to observe how frequently a feeble-minded child records a very low percentile for the average of these observations.

Next are carefully recorded the Binet age, in accordance with the Leland Stanford revision, checked by the Porteus, and, if necessary, other standardised mental tests, and the intelligence quotients of the tests duly recorded.

A clinical history, which is primarily aimed at eliciting any possible cause of arrested neuronic development, is sought, as is also a personal history of the habits and reactions of the child, together with an account of his educational work and social environment.

With all these facts before the observer, the diagnosis, in expert and trained hands, ceases to be a matter of guesswork, but becomes one of absolute certainty.

Amongst the *advantages of this method* may be mentioned the following:—

1. The individual is measured against the normal standard of the children of his own age, a proceeding which eliminates the personal element of prejudice. Nature is made to tell her own story. The method is, therefore, an objective, not a subjective, one, though the interpretation of the observed facts necessarily calls for considerable skill and accurate knowledge of an extensive kind.

2. No case of mental deficiency can escape detection, as what one part of the method fails to discover another will reveal.

3. Some indication is almost always obtained as to whether the individual can be trusted by society to control the instinctive activities of the infra-granular layer of the cerebral cortex. It is from those who cannot do so that the greatest danger threatens, and it is in precisely these cases that the brain capacity portion of the method is most likely to be accurate, because the departure from the normal is sufficiently gross as to be capable of detection, even by the present imperfect method of head measurement, and even then the diagnosis does not rest on this alone, but must be confirmed by the other avenues of approach employed.

4. It is the only method which seeks to correlate the observed mental phenomena with modern neurology.

As this last is the really important part of the method, it may be useful to summarise our *conclusions as to the value of head measurement* in the diagnosis of mental abnormality.

1. Head measurement, and the calculation therefrom of the cubic capacity of brain, is not a measure of intelligence.

2. As mental development is entirely dependent on numbers of fully-developed neurones, striking deviation of brain size from the normal will tend to be associated with mental abnormality. When this deviation attains a certain sufficiently high degree, it must be revealed by head measurement, and the calculation therefrom of brain size. One in every two of the feeble-minded have abnormal heads—a statement well within the truth.

3. As such cases of striking deviation from the normal are due, in many cases, to developmental failure of the supra-granular layer of the cerebral cortex, that is, the layer of control and educability, and as this necessarily means a greatly diminished number of myelinated axons, there must result, providing there be no compensatory increase of neuroglia or cerebro-spinal fluid, a smaller-sized brain, which head measurement, even in its present imperfect stage, is quite capable of detecting.

4. A diminished number of neurones denotes a diminished degree of intelligence. If these be chiefly supra-granular, then the reactions or behaviour of the individual will be more nearly animal in character than human.

5. Small-headedness is, as a general rule, of more diagnostic significance than large-headedness.

6. Our percentile tables of brain capacity, now available for the first time, are distinct aids in the diagnosis of mental subnormality, and afford a more certain basis for the neuro-psychologist to work upon than has hitherto been the case, because they afford a clue, in at least some cases, to the relative degree of development of the all-important supra-granular layer of the cerebral cortex.

It is this last fact which has given this work its value.

In the essential work of post-war education and reconstruction, there are two great problems—the one concerns the normal child, the other the mentally subnormal. Amongst the normal school population, one of the most urgent things is the removal from their ranks of the feeble-minded—the grit in the wheels of the educational machine.

LECTURE 3.—THE PSYCHOLOGICAL FAILURES OF LIFE.

The Director of Education (Mr. Frank Tate, C.M.G., M.A.) presiding.

Mr. Director, Mr. Dean, Ladies and Gentlemen,—

The war has thrown a lurid light on the many evils and dangers threatening the social fabric. Any community which comprises an appreciable percentage of unrecognised mentally deficient persons will be handicapped by a corresponding amount of social inefficiency.

The *legal definition of mental deficiency,* as given in clause 1 of the Mental Deficiency Act of 1913, England, is, "Persons in whose case there exists from birth, or from an early age, mental defectiveness, not amounting to imbecility, yet so pronounced that they require care, supervision and control for their own protection, or for the protection of others." This is clearly a definition which does not define. It merely postpones the recognition of the mentally deficient until such time as the commission of a crime, or offence, against society makes it obvious that such an individual should be segregated.

Tredgold suggests a *definition based on industrial ability.* He says, "The term 'mental deficiency,' in my opinion, should be restricted to those persons who are so lacking in general mental capacity and in commonsense, that they are incapable of subsisting by their own unaided efforts." As some mental defects are quite capable of earning their own living, whilst others "subsist unaided" by means of crime, prostitution, etc., the definition can hardly be considered satisfactory.

The *British Royal Commission,* in 1908, defined mental deficiency, or what in America is termed feeble-mindedness, as follows:—"A state of mental defect from birth, or from an early age, due to incomplete cerebral development, in consequence of which the person affected is unable to perform his duties as a member of society in the position of life to which he was born." This is a more satisfactory definition, inasmuch as it combines the physical cause with the social effect.

It is a general, though little thought of, truth, that all children are born idiots, dumb, and practically blind, and that in their growth they pass through all the stages of idiocy, imbecility, and moronity, to the normal, or even to genius. (See Figure 8.) Their passage from one phase to another being marked by an ever increasing number of myelinating neurones. Mental backwardness, feeble-mindedness, mental deficiency, or moronity—call it what we will—is an arrest

of this normal brain development, a stoppage of mental development, at some time previous to adolescence. This arrest is not necessarily sudden, but is much more usually gradual, the slowing down of brain growth covering several years. Whilst it is as yet hardly possible, scientifically, to estimate the precise grade of this backwardness, it has hitherto been the practice to endeavour to do so by expressing the degree of mental backwardness in terms of years, thus:—

A mental age of from 1 to 2 years denotes idiocy.

A mental age of from 3 to 4 years denotes low grade imbecility.

A mental age of from 4 to 6 years denotes middle grade imbecility.

A mental age of from 6 to 7 years denotes high grade imbecility.

A mental age of from 7 to 8 years denotes low grade moronity.

A mental age of from 8 to 10 years denotes middle grade moronity.

A mental age of from 10 to 11 years denotes high grade moronity.

A more scientific classification is that of Healy. He divides the mentally subnormal into two main groups, the mental defectives, and individuals who are defective in special and limited abilities only, but who, otherwise, are mentally normal. The definitely mentally defective Healy further subdivides into feeble-minded and the mentally subnormal, and amongst the former recognises idiots, with a Binet mental age of two years; imbeciles, with a Binet mental age of from two to seven years; and morons, with a Binet age of from seven to twelve years.

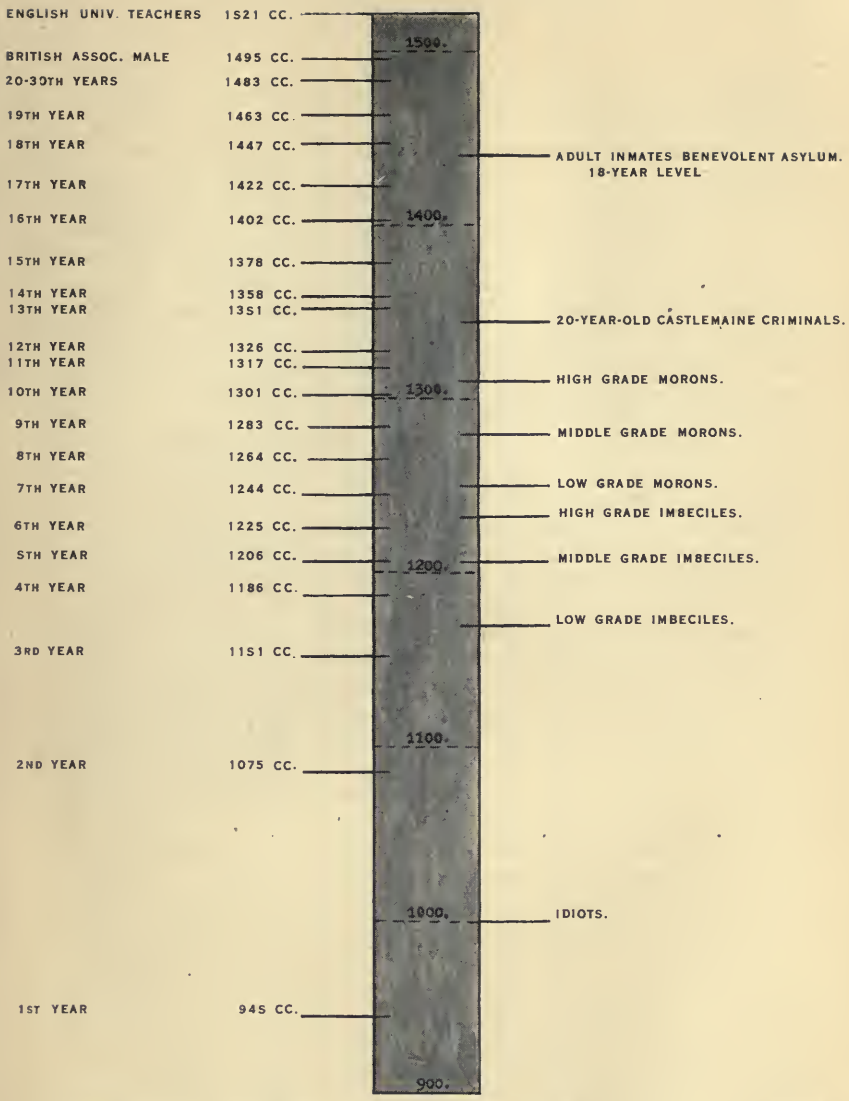
In illustration of this *psychological classification of gross mental subnormality,* there were thrown upon the screen the following clinical cases:—

Male, Aged 38 years; Mental Age 2.—Has all the characteristics of the idiot, except that he has been trained a little more than is usual with the idiot. The mother was insane and blind. The maternal grandfather died of paralysis, and the father and paternal grandfather were both alcoholics.

Male, Aged 18 years; Mental Age 2.—An untrainable idiot. Cannot dress himself, and cannot talk—he only chatters.

Male, Aged 12 years.—Mongolian imbecile.

A group of school children of various ages, all belonging to the class of morons. The higher grades of morons are but little removed from the dull and backward of the normal population. It was these milder grades which were illustrated.



THE CEREBRAL GROWTH OF THE NORMAL INDIVIDUAL.

THE MENTAL LEVELS OF THE ABNORMAL INDIVIDUAL. THE BODY CONTINUES TO GROW TO THE ADULT STATE, BUT NEURONIC GROWTH IS MORE OR LESS INCOMPLETE.

FIGURE 8.

To illustrate brain growth in the normal individual, as contrasted with the mental levels of the abnormal. (Berry.)

Of arrested cerebral development due to recognisable physical causes, there were shown on the screen the following illustrative cases:—

An adult microcephalic idiot who was also the subject of epilepsy.

An adult female microcephalic idiot who was a tolerably good worker in the wards of the institution in which she was segregated.

A hydrocephalic imbecile, where the size of head was due to excess of cerebro-spinal fluid, and the imbecility to lack of neurones.

A female sporadic cretin, aged 20 years, with the bodily and mental development of an infant, the arrested cerebral growth being due to altered internal bodily secretion.

An adult female, the subject of inherited syphilis. The congenital poison having arrested neuronic growth, has resulted in mental deficiency.

A boy, aged 9 years, and a pronounced imbecile, mischievous, destructive and intractable. The mental condition being due to arrested neuronic growth, following an attack of encephalitis in infancy.

The foregoing types of amentia, whether psychological or physical, are all quite easily recognisable, even by a layman, but it is important to realise that they constitute only from 20 per cent. to 30 per cent. of the total of mental defectives. The remaining 70 per cent. can only be diagnosed by experts specially trained and qualified in the latest methods of mental research and diagnosis. Of this remaining 70 per cent., "the first point to be emphasised," says Goddard, "is that these people cannot be recognised by their physical appearance. The most dangerous group of mental defectives are those who are in no way different from the intelligent man, and not only in outward appearance, but in conversation and bearing, these people often pass for normal. They are thought to be simply untutored, and it is supposed that training will bring them up to the standard. But that such is not the case is testified to by the presence of hundreds of such cases in our institutions for the feeble-minded, and by thousands of others who are not in institutions, but who are recognised by those who know the feeble-minded as being mentally weak."

As regards the *causes of cerebral amentia,* it is difficult in the present state of knowledge, to do more than lay it down as a working proposition, that anything which interferes with the normal development of the neurone will produce some form of partial or complete feeble-mindedness. Amongst such predisposing or causative factors are probably the following:—

1. Heredity is by far the most frequent and the most potent predisposing cause of nervous and mental disease. What the child inherits is not so much a disease, as an unstable nervous system. In feeble-mindedness, the influence of heredity is so potent that, even if only one parent is mentally retarded, the children will rarely be up to the normal standard. Where both parents are defective there is no escape.

2. As regards the parents, drunkenness of a chronic character would appear to manifest itself in the offspring in the form of idiocy imbecility, and epilepsy. The children of such parents are apparently born with a defective nervous organisation, and such weak inhibitory will-power as to make them fall an easy prey to social temptations. That congenital syphilis is a cause of arrested neuronic development is undoubted.

3. Of pre-natal conditions it would appear to be certain that improperly applied forceps may do irreparable damage to the delicate neurones of the brain, possibly by causing a sub-dural haemorrhage. Unsuccessful attempts to procure abortion may also possibly act injuriously on the developing neurone.

4. Of the post-natal causes of cerebral amentia, insufficient or improper feeding during infancy, febrile diseases during early childhood, and bad hygienic conditions, particularly an insufficiency of oxygen, are all factors in arresting normal neuronic growth and development. The neurone is particularly susceptible to deprivation of oxygen.

5. Of the social factors during childhood there may be mentioned as contributory causes, the environment, bad companionship and evil influences, and defective and insufficient education. These either convey the wrong series of afferent impressions to the child's brain, or by a lack of afferent impressions, as from insufficient education, certain of the short association neurones of the cerebral cortex may fail to myelinate, that is, will not function.

"Incapable themselves, the feeble-minded freely propagate their kind. They have, on the average, twice as many children as do normal people. If both parents are feeble-minded, all the children will be; if one parent is feeble-minded, half the children will be. Two-thirds of the feeble-mindedness in the United States has been inherited. *Feeble-mindedness is incurable.*"

Goddard's "Feeble-mindedness, Its Causes and Consequences," published in 1920, contains many singularly instructive examples of the influence of heredity as a causative factor in the production of feeble-mindedness. The photographs, genealogical tree and clinical histories of Florence T.

and her brother, Byron T., described and figured on page 52 of Goddard's work, were thrown upon the screen as typical examples of heredity.

The history of Martin Kallikak is also a singularly instructive example of the influence of heredity, and of the enormous cost to the community of feeble-mindedness. The case has been fully investigated by Goddard. Kallikak, who was a soldier in the American Revolutionary war, had, before he was twenty-one, illegitimate relations with a feeble-minded girl, by whom he had a son. Subsequent to the war he married a normal woman, and became a normal, law-abiding citizen. His descendants by these two women have been traced to the number of 480 by the feeble-minded woman, and 496 by the normal mother. Of the former, 143 were feeble-minded, 36 were illegitimate, 24 were confirmed alcoholics, 3 were epileptics, 82 died in infancy, 3 were criminals, and 8 kept houses of ill-fame. In the descendants of the normal mother there have been none such. On the contrary they are doctors, lawyers, judges, educators, traders—in short, respectable citizens, men and women, in every phase of social life. There have been no feeble-minded among them; no illegitimate children; no immoral women. There has been no epilepsy, no criminals, no keepers of houses of prostitution. Only fifteen children died in fancy.

As *an example of the effect of deprivation of oxygen* in the production of feeble-mindedness, the work of Dr. J. H. Waite, of the Rockefeller Institute, on the effects of hookworm infection upon the mental development of North Queensland school children may be cited. Writing in the "Medical Journal of Australia," on the 4th January, 1919, Dr. Waite says, "The direct outcome of the results of the hookworm disease, which is preying upon 40 per cent. of the total school population from Cooktown to Townsville, and is stamping serious mental, physical, and sexual degeneracy upon 25 per cent. of the total school population, can be nothing other than the weakening of the social fabric and the unfitting of the coming generation for the struggle for existence. The tendency of the disease is towards the obliteration of the race. . . . To the economic loss from social inefficiency must be added the wasted educational effort of 4000 teachers, trying to carry along 40 per cent. of relative mental deficients and mental laggards among their classes." Part, at least, of the explanation of the hookworm as the cause, and the mental deficiency as one of the effects, is, of course, that the parasite feeding upon the blood reduces the amount of haemoglobin. This, in its turn, reduces the supply of oxygen, and the growing neurone, being peculiarly susceptible to the deprivation of

oxygen, fails to complete full development, and some form of feeble-mindedness results.

Of the other possible causes of mental deficiency it is not necessary to speak, but sufficient has been said to make clear the suffering and economic loss to the community produced by failure to grapple with the problem.

Attention may next be directed to the *numbers of the feeble-minded present in any community*—a subject upon which, in the absence of complete surveys of the school-going population, it is impossible to speak with that precision which should characterise a scientific pronouncement.

The British Royal Commission on the Feeble-minded found a percentage of 0.86 per cent. of the entire school-going population of England and Wales mentally defective, and a percentage of 0.36 per cent. of the entire population. As it is more than probable that these results were not based upon that thorough investigation upon which diagnosis is now made, it seems almost certain that these percentages include only the very obvious cases of high-grade imbecility and low-grade moronity.

Professor Karl Pearson estimates the percentage of feeble-minded for the entire population of Great Britain at 0.46 per cent.

Goddard found nearly 2 per cent. of the school-going population in certain districts in America mentally defective.

Cyril Burt stated in 1917 that of the children over 9 and under 15, attending the ordinary schools of the Borough (London), nearly 4.2 per cent. are backward by 3 years or more, and that if the lower age limit be extended from 9 to 5 years, and include those backward by 2 years, the apparent number rises to 9.5 per cent.

Even though these percentages of the incidence of moronity were correct, they could only be regarded as negligible by the most careless and casual thinkers, because the danger and cost to the community cannot be estimated by the mere incidence of moronity alone, in support of which statement there is much evidence, of which the following must suffice:—

Of the *great importance of a study of moronity to the criminologist,* there can be no question. Dr. William Healy, who has had much experience of juvenile crime in his capacity as Director of the Psychopathic Institute in Chicago, says, "Mental defect forms the largest single cause of delinquency . . . defective offenders, in most cases, prove, upon study, to be individuals who easily succumb to social temptations, easily learn from vicious examples, and are easily stimulated to develop criminalistic trends of thought. In other words, in these highly representative members of the so-called criminal

types, one must conclude that the development of criminalism is partially the result of environment, as well as of innate tendencies."

In 16 typical American Reformatories, Juvenile Courts, Homes for Prostitutes, etc., Goddard found the percentage of mentally defective inmates ranged from 28 per cent. in the Lyman School for boys, Westboro, Massachusetts, to 89 per cent. in Geneva, Illinois—the last being the result of a Binet examination only. The average percentage of mentally defective persons in the 16 institutions being just over 64 per cent., that is, two out of every three, are mentally defective.

Of 27 male criminals hanged for murder in Melbourne, only 7 were found at normal levels. Amongst the grossly abnormal members of the seven was the notorious Deeming, whose cubic capacity of brain was only 1358 cc., or 18 cc. less than the true mean capacity of brain of a normal 13-year-old schoolboy, which is suggestive of Deeming's having been a low grade moron of the microcephalic type.

In an examination of the inmates of the Castlemaine Reformatory for Indeterminate Sentence criminals, Mr. Porteus and I found that whilst the chronological age was about 19 years, the average brain capacity was that of the 14-year-old schoolboy, with an average mental age of 10 years.

From these typical instances of the correlation between crime and mental deficiency, it may be concluded, with Goddard, that "at least 50 per cent. of all criminals are mentally defective. Even if a much smaller percentage is defective, it is sufficient for our argument that, without question, one point of attack for the solution of the problem of crime is the problem of feeble-mindedness."

As with crime, so with prostitution. Dr. M. W. Barr found amongst 424 prostitutes, more than 80 per cent. who were distinctly imbecile, their mental age not exceeding 12 years. Of the 20 per cent. adjudged normal, a large majority were found to be unable to carry on a consecutive conversation, and never reading papers or books, were absolutely ignorant of the ordinary topics of the day. Of the whole, the most of them had contracted venereal disease, and were pronounced alcoholics and drug fiends.

The Children's Bureau of Philadelphia, as the result of an investigation of feeble-minded women, reached the following conclusions:—"Practically all poor feeble-minded women at large become the mothers of illegitimate children soon after reaching the age of puberty. Feeble-minded women produce many children. In this series, 20 *feeble-minded women produced* 60 *children.* The helpless feeble-minded woman is the prey of not one man, but many men. Most of the children of

feeble-minded women are either illegitimate or feeble-minded, or both. The histories of these feeble-minded women and of their feeble-minded children are practically the same. Their unfortunate birth, helplessness, pauperism and ruin is part of a continuous series, whereby the community is constantly supplied with the elements of degeneracy."

To the alienist, the early recognition of mental instability as a factor in the prognosis of insanity is again of greater importance than is, perhaps, generally realised. Dr. Fryer Ballard, in his "Epitome of Mental Disorders," 1917, says, "Some few stocks, contrary to the usual laws of nature, exhibit a greater tendency towards insanity than towards normality. . . . This inherent tendency to insanity can, with care, very often be detected in childhood or adolescence, and its development into mental disease can, in many cases, be prevented by suitable measures. If family doctors only recognised signs of mental instability in their young patients, the incidence of mental disorders would be reducible in no small degree." Of this type, a boy, aged 9 years, whom I saw two years ago, furnished a remarkable instance of uneven mental development. He could not only name the day of the week that any date during the past two years fell upon, but he could also state, apparently quite accurately, what he was doing and where he was on such date. In all other respects he is a prospective victim of morbid mental processes.

To the educationist the importance of an individual and scientific study of the child cannot be overestimated. Professor Terman says, "We have lately awakened to the fact that each year one child in six or seven fails of school promotion, and that this wholesale elimination involves boys to a greater extent than girls. That girls of a given age make better marks than boys in their class work and in examinations. That many weakly pupils break down in the effort to keep up with the class in which their chronological age places them. That education from top to bottom needs more than anything else to be individualised."

To the community as a whole the need for a scientific survey of the school-going population, and the elimination therefrom of the mentally defective, has become a national necessity if the ravages of war are to be eliminated within the next generation, and it has become so both from a humanitarian standpoint and from the economic. Its continued neglect spells bankruptcy—both moral and financial. That this is so, let a few general observations suffice to prove.

In every community, prostitutes and criminals are largely recruited from the ranks of the morons, but, unfortunately, the danger to society does not stop even at this, for every

soldier and every sailor is liable to have sentry duty, and in such a position a moron would be but a man of clay, who might betray an entire army or wreck a fleet. Dr. Goddard says, "Mental incompetency explains the action of the unsatisfactory recruit more often than any other cause. Perhaps more often than all other causes put together."

Industrial concerns suffer enormous losses from the employment of persons whose mental ability is not equal to the tasks they are expected to perform. The present methods of trying out new employees, transferring them to simpler and simpler jobs, as their inefficiency becomes apparent, is wasteful and unnecessary. Any business employing as many as 500 or 1000 workers could save the salary of a trained medical psychological expert several times over.

Professor Terman tells us that "It hardly needs to be emphasised that when charity organisations help the feeble-minded to float along in the social and industrial worlds, and to produce and rear children after their kind, they are performing a service of very doubtful utility. A little expert psychological assistance would aid the united charities of any city to direct their expenditure into more profitable channels than would otherwise be possible."

Dr. Groszman, writing in 1917, says, "We may admit that aments or feeble-minded can have as little recognition as independent citizens of a political body as have dements or insane, and it may also be accepted that the dull portion of our Commonwealth, they who can hardly be expected to have a clear conception of the purposes and responsibilities of government . . . . 'voting cattle,' as they are sometimes called . . . form a grave problem in the regulation of civic rights."

When we have learned the lessons which neuro-psychology has to teach, we shall no longer blame mentally defective workmen for their industrial inefficiency, punish weak-minded children because of their inability to learn, or imprison and hang mentally defective criminals because they lack the neuronic mechanism to react along the lines which modern law and usage regard as normal for normal persons.

Whilst most intelligent thinking people are generally familiar with the social results of amentia just referred to, there are but few who realise the enormous financial cost to the community of our continued failure to grapple with the problem in the only effective manner—that is, by early diagnosis and segregation. "It costs the citizens of the United States 1100 million dollars a year for police, courts of justice, prisons, charities and correction, and similar forms of self-protection against the festering human refuse heap. It is a

curious fact that the nation is spending only 600 million dollars annually for schools, churches and other constructive agencies. In other words, 500 million dollars less is spent to develop human assets than is spent to keep up the human failures." (Groszman.)

No nation which hopes to make good the economic wastage of the war can afford to throw so much money on to the rubbish heap.

What then is the solution? The first essential is correct and early diagnosis in childhood by specially trained teachers, and the second is segregation colonies, under medical observation.

As regards the first point, Professor Karl Pearson, in 1914, stated his belief that the term "mental defective" ought to be replaced by some such term as "social inefficient"—a view with which I entirely concur. He adds, "We have to see that we are really on the fringe of the biggest problem of the modern state—the question of social inefficiency. How are we to discover *a priori*, from the school inefficients, the social inefficients of adult life?"

I venture to suggest that the method of diagnosis devised, advocated and employed by Mr. Porteus and myself, is now a sufficient answer to Professor Pearson's question, and that such observations, carried out under medical supervision, and interpreted by skilled neuro-psychologists, will inevitably detect, during childhood, those who must eventually become social inefficients—and the claim is not made on mere laboratory investigation, but has stood the test of actual clinical practice, not once, but many times. It will be instructive to place two of our cases side by side, the one a boy, the son of wealthy parents; the other a youth, the son of poverty, not seen until after the commission of a crime.

CASE 1, BOY, AGED 15 YEARS.

CLINICAL HISTORY—

Had infantile paralysis at 18 months.
Convulsions in infancy.
Partial right-sided hemiplegia.
Sexual characteristics and habits over-developed.

CASE 2, YOUTH, AGED 19 YEARS.

Was convicted as a habitual offender and awarded an indeterminate sentence.
Confined in Castlemaine Gaol, Victoria.
His last crime was that of setting fire to a house, with a desire to see the inmates burn.

CEREBRAL EXAMINATION. THE BRAIN—	
1095 cc. Below the 10 percentile for his age group.	1248 cc. Below the 10 percentile for his age group.
PHYSICAL EXAMINATION. THE BODY—.	
Weight, stature, sitting height. Average percentile 63.	Below the 10 percentile.
PSYCHOPHYSICAL EXAMINATION.	
Vital capacity, and grip. Average percentile 32.	Below the 10 percentile.
PSYCHOLOGICAL EXAMINATION. THE MIND—	
Porteus tests: Mental age 8 years. Impulsive and imprudent. No planning capacity or foresight.	Mental age 7 years. No capacity for forethought. Highly suggestible.
Binet tests: Mental age 8 years. Weak in ability to memorise and to sustain attention. Range of ideas very narrow.	Mental age 7 years. Cannot recognise the four colours, red, blue, yellow, and green. Cannot repeat 5 numerals, nor count backwards from 20, nor perform the simplest money operations.
EDUCATIONAL AND SOCIAL. THE ENVIRONMENT—	
Of good family. Parents wealthy. Boy lacks for nothing, but has already been in the hands of the police for stealing a watch. Lies, steals, and is a public masturbator at school. Makes no progress with his work. Is still in preparatory grade.	Father is a woodcutter, and in poor circumstances. Boy has had no education. Can neither read nor write. Has helped his father until conviction.
DIAGNOSIS—	
A low-grade moron. Neuronic deficiency due to arrested development following paralysis.	A high-grade imbecile. Mental condition not recognised by anybody until time of expert examination.
Morally irresponsible.	Utterly unfitted to be at large, but quite irresponsible for his "crimes."
PROGNOSIS—	
Under a different social environment an undoubted future criminal.	Has necessarily developed into a criminal, because his environment prevented his condition being detected during early youth.
Society had been saved from his depredations because the parents were able to obtain expert advice whilst he was still at school.	Requires segregation in a colony for mentally defective persons.

These two cases, which are not isolated examples, should convince even the most sceptical that it is now possible to make, in early childhood, a reasonable forecast of the future social reactions of, at least, some of the more pronounced cases. Had this been done in early youth with case number 2, society would not now be put to the expense of supporting him in a gaol, because he would have been placed in a segregation home, and could probably have been taught to earn his "keep" by performing that particular class of manual work which the examination showed he was best fitted for, namely, horticultural and agricultural.

In Australia, at all events, there is very urgently needed a Child Study Clinic or Laboratory for the scientific study of the growing child—whether normal or abnormal. Such a clinic was established some years ago in the University of Pennsylvania, in answer to a direct call from the educational world. Its functions are:—

1. To investigate the phenomena of mental development in school children, as manifested more particularly in mental and moral retardation, by means of the statistical and clinical methods.

2. To establish a child clinic, supplemented by a training school in the nature of a hospital school, for the treatment of all classes of children suffering from mental retardation or physical defects interfering with school progress.

3. To offer practical work to those engaged in the professions of teaching and medicine, and to those interested in social work, in the observation and training of normal and retarded children.

4. To train students for a new profession, that of child study expert, who would find his or her career in connection with the school system, through the examination and treatment, under medical supervision, of mentally and morally retarded children, or in connection with the practice of medicine.

During the past three years it has been my privilege to deliver a series of lectures on this subject in five out of the six Australian States, with the object, if possible, of sufficiently arousing public opinion to the necessity of establishing such an institute in Australia. In January, 1920, the Premier of Western Australia, Mr., now Sir James, Mitchell, wrote to the Premiers of all the Australian State Governments, stating, "This Government will assist in the establishment of a child study clinic on the following basis, viz.:—Provided that not less than three other States co-operate, the Government of Western Australia will contribute a proportionate share, on a basis of population, towards its establishment and mainten-

ance for a period of ten years, the total annual contribution by all contributing States not to exceed £7000."

It is understood that this generous and enlightened offer was accepted by two States only. The other States have either done nothing, or have preferred to act independently. In any case, the conditions of the original offer have not been complied with, and hence Australia is still without its child study clinic, and this, notwithstanding that its establishment has commanded a large amount of public support, both from within and from without Australia.

Without co-operation it does not appear probable that any one of the States can undertake that survey of the school-going population of Australia, which is so essential if the problem of the feeble-minded is to be effectually handled. A central Child Study Clinic, on the other hand, would, by training selected teachers from all the States to recognise mental subnormality by standardised methods, ultimately result in curtailing the reproduction of feeble-mindedness, and in the elimination of an enormous amount of crime, pauperism and industrial inefficiency. The high-grade cases of feeble-mindedness, now so frequently overlooked, are precisely the ones where it is most important for guardianship to be assumed by the State.

The industrial world has long since learned that, in the process of converting raw material into a finished product, waste must be reduced to a minimum. We are beginning to discover that one of the most important raw materials—the human material—is being most wastefully treated. The business of life needs to be placed on a basis of efficiency. The saving is not merely one of money, but, what is vastly more important, human souls.

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